A Structural Integrity Study for
Permanente Creek Flood Control Project

Los Altos and Mountain View, California

Prepared for:
Santa Clara Valley Water District

Prepared by:
Biggs Cardosa Associates, Inc.

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Santa Clara Valley Water District

PERMANENTE CREEK PLANNING STUDY

Located in Santa Clara County, CA

STRUCTURAL INTEGRITY STUDY

September 13, 2000

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Permanente Creek Planning Study
Located in Santa Clara County, California

Structural Integrity Study

Project No. 1999 029

This Structural Integrity Study report was prepared by Biggs Cardosa Associates, Inc. in general accordance with the scope of work as per our agreement with the Santa Clara Valley Water District. The recommendations in this report are based on as-built data, site investigations, geotechnical investigations, material testing data, and standard engineering practice. Due to the inherent limitations in site investigations, geotechnical investigations and materials testing, it is neither uncommon to encounter unforeseen variations in conditions along the project alignment nor is it practical to determine all such variations during a program of testing and investigation for a project of this scope. Such variations, when encountered, generally require additional engineering services to attain a reasonable explanation and resolution.

STRUCTURAL INTEGRITY STUDY

FOR SANTA CLARA VALLEY WATER DISTRICT'S

PERMANENTE CREEK PLANNING STUDY

LOCATED IN SANTA CLARA COUNTY, CALIFORNIA

EXECUTIVE SUMMARY

INTRODUCTION

This report presents the study process and results of the *Structural Integrity Study* (Study), part of the Santa Clara Valley Water District's (District's) comprehensive *"Permanente Creek Planning Study located in Santa Clara County, California."* The purpose of the Study was to investigate the condition of concrete channel facilities along Permanente and Hale Creeks from the upstream end of the Cargill Salt Ponds to Foothill Expressway, including the Permanente Diversion. The project alignment is located in the cities of Los Altos and Mountain View. The Study was conducted to determine the reasons the channel facilities were showing signs of deterioration, and included:

- An evaluation of the original channel design and construction and current structural and geotechnical conditions,
- An estimation of the remaining life of the concrete facilities, and
- Development of recommendations for repair or replacement measures, maintenance, and monitoring programs.

The results of the Study will be used to assist the District in: 1) assessing the severity of the channel structure deterioration, and 2) prioritizing recommended channel repair and replacement work. General conclusions developed for the project alignment (such as deficiency patterns found, remaining life expectancy, type of rehabilitation and associated costs) may be used in the future to prioritize repair or replacement work for similar facilities in the District's other creek alignments. In addition, the results of the Study were used to develop design recommendations and estimated costs for the repair and replacement of similar concrete channel facilities.

SUMMARY OF FINDINGS, CONCLUSIONS, AND RECOMMENDATIONS

Approximately 8,200 meters (5.1 miles) of vertical walled channels, trapezoidal channel linings, and concrete box culverts were investigated. These structures were originally built in the 1960s and are starting to show signs of structural problems common to facilities of similar age in other cities and agencies throughout the country. In general, the original designs were in conformance with the design code and standard practices of that time. However, construction deviance and an out dated understanding of soil/structural interaction produced unanticipated structural and maintenance problems that can lead to a reduced structure life. The expected life span of properly designed and constructed concrete channel facilities is approximately 50-60 years from construction but can be reduced to 45-50 years or less due to structural problems.

The studied alignment was divided into channel segments that corresponded to the District's reach designations. For each segment, pertinent deficiency patterns were identified along with the stationing of the affected reach. The remaining life expectancy was then estimated as falling into one of four age range categories: 0-5 years, 5-10 years, 10-15 years, and greater than 15 years. Imminent structural concerns for channel segments were identified, and appropriate repair and replacement options and costs were developed.

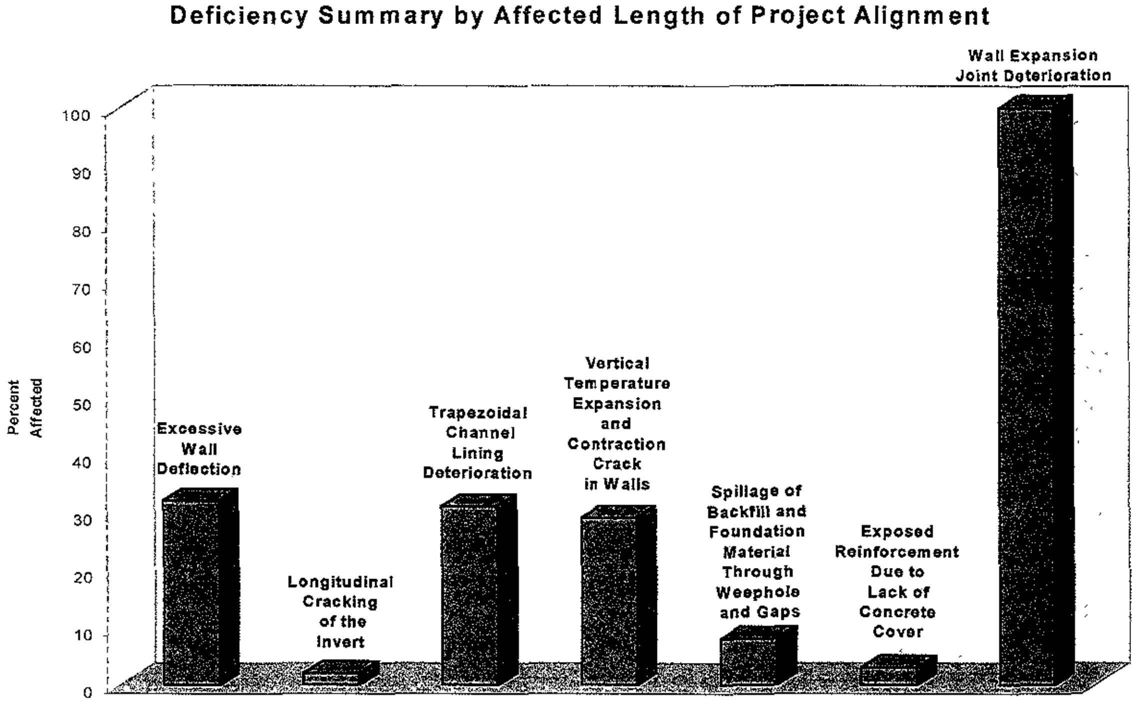
Deterioration Patterns

The project alignment investigation revealed there were seven distinct patterns of deterioration or deficiency. Two of these deficiencies pose a structural stability concern:

1. Excessive wall deflections, which occurred over 3,005 meters (9,858 feet) of the Permanente and Hale Creek alignments with varying degrees of severity, and

2. Longitudinal cracking of the invert slab, which occurred over 222 meters (728 feet) of only the Hale Creek alignment.

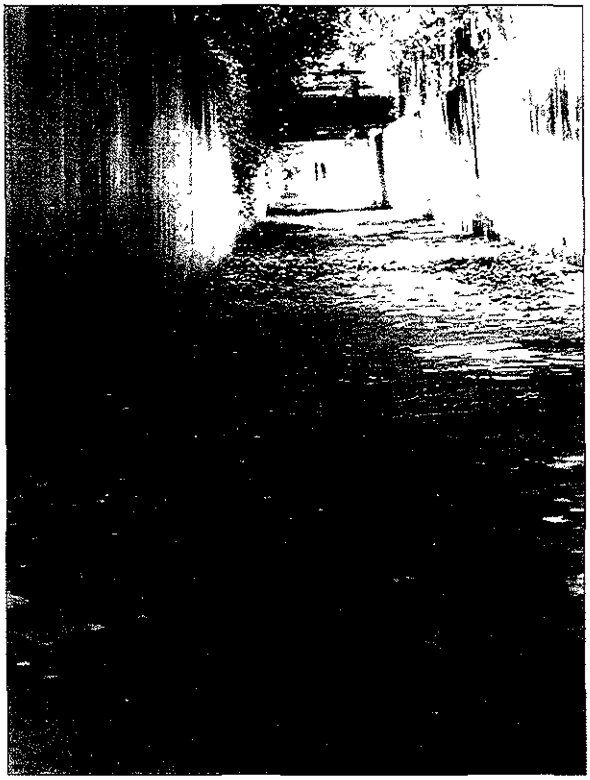
The other five deficiency patterns, although not a structural stability concern, contribute to the reduced life of the facilities and include: 1) trapezoidal channel lining deterioration, 2) vertical temperature expansion and contraction cracks in walls, 3) spillage of backfill and foundation material through weepholes and gaps, 4) exposed reinforcement due to lack of concrete cover, and 5) wall expansion joint deterioration. The following chart summarizes the affected lengths by deficiency pattern. Wall expansion joint deterioration occurred along 100 percent of the studied alignment and was the most prevalent deficiency pattern. Excessive wall deflection was the second most prevalent deficiency pattern, but also the most severe in terms of its affect on the structural stability of the channels. As shown on the chart, less than 50 percent of the project alignment contained any one of the other deficiencies, which indicates an overall decline in the state of the facility is occurring, but it has not yet affected the majority of the channel structures.



The following photographs illustrate 1) excessive wall deflections, and 2) longitudinal cracking of the invert (the floor of the channel), the two most severe deficiencies in terms of the structural stability of the channels.

Photograph 1 - Excessive Wall Deflection (Permanente Creek Reach No. 15B)

Photograph 2 - Longitudinal Cracking of the Invert (Hale Creek Reach No. 5B)

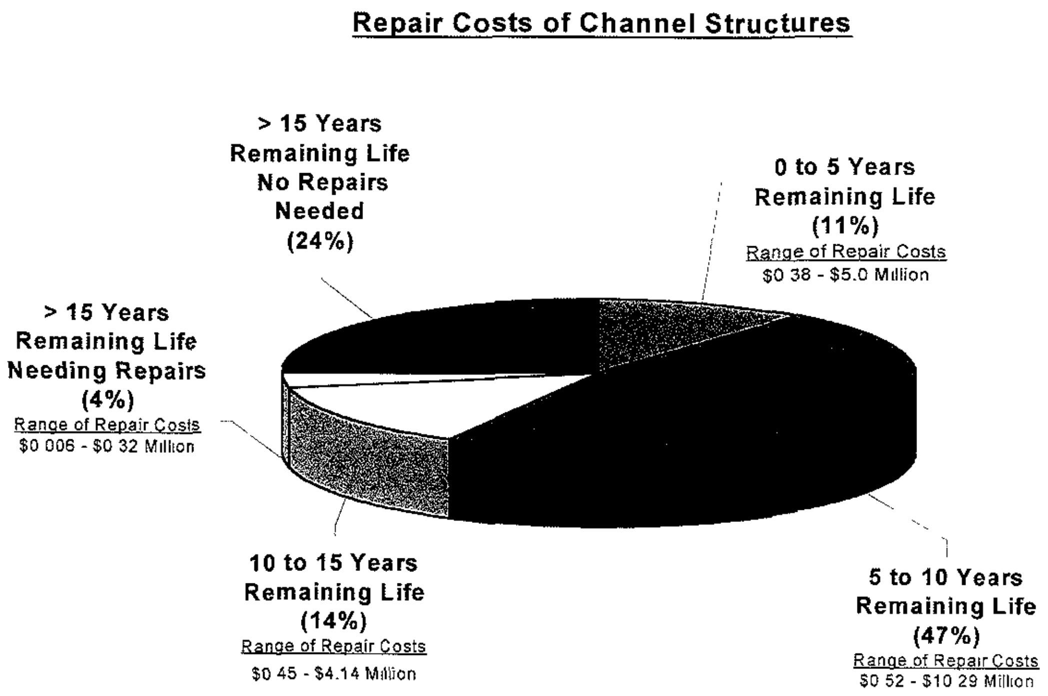


Affected Channel Lengths and Estimated Remaining Life

Of the total 8,200 meters (5.1 miles) of channel length investigated, the following remaining life expectancies were estimated for the project alignment:

- 0-5 Years: 827 meters (2,713 feet) of channel length
- 5-10 Years: 3,979 meters (13,054 feet)of channel length
- 10-15 Years: 1,001 meters (3,284 feet) of channel length
- >15 Years: 2,393 meters (7,850 feet) of channel length

Based on the estimates, greater than half of the facility's channel structures have less than 15 years of remaining life. The chart on the following page illustrates estimated remaining life expectancies for each portion of the studied alignment and summarizes the associated range of costs for repair or replacement to increase the life expectancies. As shown on the chart, 72 percent of the facility requires some sort of repair or replacement in the next 15 years to maintain its structural stability.



Note: Annual Maintenance Cost is estimated at $50,000 for the entire project alignment (See Section-4.3 "Channel Inspection and Maintenance Program" for expanded details of the Inspection and Maintenance Program).

In addition to the recommended repairs or replacements summarized below, a channel inspection and maintenance program consisting of semi-annual inspection walk throughs of the entire project alignment was developed at an estimated cost of $50,000. This program is intended to monitor the ongoing deterioration and maintain the structures, because a significant portion of the project alignment was affected by various deficiencies and the structures have limited life expectancies as shown above.

Repair and Replacement Recommendations

For each deficiency, a corresponding course of action for its repair was recommended. Some deficiencies had multiple recommended repair options. For the two deficiencies that posed a structural concern (excessive wall deflections and longitudinal cracking of the invert), five repair alternatives were developed varying from complete redesign and replacement of the channel segment to structural fixes for the existing channel to meet the restrictive right-of-way limitations (1 to 5 feet) as follows:

1. Total redesign and replacement of the channel section.

2. Install vinyl sheet piling behind the existing vertical walled channel section.

3. Construct a reinforced concrete facing wall in front of the existing deflected walls. Concrete facing with struts.

4. Construct a reinforced concrete facing wall in front of the existing deflected walls. Concrete facing with piles.
5. Construct vertical walled bents at regular intervals and utilize the existing concrete walls and slab by attaching the existing concrete to the vertical walled bents with dowels.

For the other deficiencies, repair options varied from total redesign and replacement to monitoring the deficiency. Repair options were developed for each channel segment along with the associated repair cost and the additional channel life the corrective measure would add to the channel.

Summary

The deterioration in various portions of the studied alignment is due to a combination of factors including age, construction details and channel type. Of the seven deficiency patterns identified, excessive wall deflections and longitudinal cracking of the invert are of the most concern in terms of the structural integrity of the channels. Less than half the project alignment is affected by each of the deficiencies (except wall expansion joint deterioration, which affects the entire project alignment), and the deficiencies range from minor to severe.

In summary, 76 percent of the project alignment will require repairs or replacement in the next 15 years to maintain its structural integrity at an estimated cost of $1.35 to $19.75 million depending on the extent of repair or replacement implemented. Of the 76 percent, 11 percent will require immediate attention in the next 5 years ($0.38 to $5.0 million), 47 percent will require attention in the next 10 years ($0.52 to $10.29 million), 14 percent will require attention in the next 15 years ($0.45 to $4.14 million) and 4 percent will require attention after 15 years ($0.006 to $.32 million).

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Supplement No. 2: Records of Telephone Conversations .... (Separate Binder)
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Supplement No. 6: Materials Testing Reports.. (Separate Binder)
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GLOSSARY OF TECHNICAL TERMS

abrasion
the wearing away of a surface by rubbing and friction

active earth pressure
the reduced lateral soil pressure acting on a wall once the wall is allowed to deflect sufficiently

alignment
course or path of the channel

as-built
the way in which the structure was constructed

as-built analysis
an in-depth examination of the completed structure based on the as-built plans

at-rest lateral pressure
the lateral soil pressure acting on a wall when the wall is unable to deflect

backfill
the soil that is placed behind the retaining wall

bar development length
the length of reinforcing bar extension required to fully develop the design strength of the reinforcing bar past the required section

blow count
the number of successive blows to drive a to pile a certain depth

cathodic protection
the practice of preventing corrosion of the reinforcing steel by suppressing current flow in the corrosion cell

collapse
the ultimate failure of a structural element

concrete cover
the amount of concrete that exists between the reinforcing bars and the exterior face

concrete facing
a layer of concrete placed over an existing or element-hardened concrete

coring

the act of drilling and removing a cylindrical sample of concrete from a structural element for testing

delamination

a separation of the layer of the concrete cover

detailing

the practice of drawing the designed elements on the contract plans. Structural details can vary with engineering judgement and are not necessarily specified by the design code. Variances in structural details can effect the structural performance of the element.

dowel

a rod that connects two concrete elements through a joint. A dowel allows rotation between the two connected ends but does not allow movement transversely to the dowel.

efflorescence

a deposit of salts formed on the surface of a concrete or masonry wall

epoxy coated rebar

reinforcing steel that has been pre-coated with an epoxy resin to enhance its resistance to corrosion

flexure

also known as bending

flexure crack

a crack that develops from bending

geometrics

the geometrical configuration or layout of a structure

Ground Penetration Radar (GPR) test

a test that uses sound waves to determine whether voids or cavities exist below or behind a solid slab or wall

half cell potential test

a test that uses the resistivity of the reinforcement to determine how corroded the surrounding bars are

hydrostatic pressure

the lateral pressure due to the presence of water

invert

the horizontal slab which exists between the walls or channel lining

longitudinal crack

a crack that runs parallel to the centerline of the channel

main reinforcing steel

the reinforcing bars that are specifically placed to resist the primary loads of an element

pacometer test

a test that uses magnetic properties of the reinforcing bars to determine the amount of concrete cover that exists over those reinforcing bars

pile

a drilled or driven underground structural element that provides both vertical and lateral force capacity

popout

the breaking away of small portions of a concrete surface due to localized internal pressure. A popout typically leaves a shallow conical depression.

pounding

the act of two adjacent wall sections colliding

rebar

also known as the reinforcing steel found within a reinforced concrete section

scaling

local flaking or peeling away of the near-surface portion of a hardened concrete

Schmidt Hammer test

a test that uses a rebound impact hammer to determine the compressive strength of the concrete

shear crack

a crack that develops from a shearing force

sinkhole

a cavity or void caused by soil erosion behind a wall or beneath an invert slab

soil corrosiveness

the potential of the soil to cause corrosion on structural elements in contact with the soil

soil anchor

a steel rod that has one end grouted into the soil and the other end embedded in a structural wall. Soil anchors are used to provide lateral stability to structural elements like vertical walls.

sounding

the act of pounding a hammer or mallet on the concrete wall or invert to determine if voids or sinkholes exist behind the wall or invert

spalling

a reduction in concrete volume by fragmentation

structural deformation
deflection of a structural element

strut
a horizontal structural element that primarily resists axial compression

surcharge loading
additional lateral loading. Examples of surcharge loading are increased levels of backfill or loads from adjacent structures or traffic.

temperature expansion and contraction crack
a crack in the concrete that develops due to the volumetric fluctuations of the concrete. These volumetric fluctuations in the concrete are caused by temperature changes of the concrete.

temperature reinforcement
reinforcing steel that is installed to control temperature cracking of the concrete. Temperature reinforcement usually consists of rebar placed horizontally along the faces of the walls and invert.

U-frame
a three sided channel section which consists of two walls and an invert that form a U-shape; also known as vertical walled channels.

U-walls
the vertical walls of a concrete U-frame channel

vinyl sheet piling
tall corrugated sheets of vinyl that are installed to retain soil. The vinyl sheet piling is driven or vibrated below ground to allow for excavation on one side of the sheet piling.

wall capacity
a measure of the wall's ability to resist the loads applied on it

wall construction joint
a joint within a wall that is primarily for construction purposes. The joint indicates where the contractor stopped and started their concrete pours.

wall deflection
a measure of the top of wall movement from the vertical as-built position

wall expansion joint
a vertical joint between two wall panels which allows for the longitudinal movements of the panels. These longitudinal movements are influenced by volumetric fluctuations of the concrete panels due to temperature changes.

wall yield deflection
the top of wall movement where yielding of the main reinforcing steel occurs

weathering

the deterioration of a material due to exposure to the outdoor elements

weepholes

a hole installed at the base of a concrete wall or lining for the purpose of providing drainage to relieve any hydrostatic pressure that may build up behind a concrete wall or lining.

weephole screen

a wire mesh installed behind the wall at a weephole. The purpose of the weephole screen is to prevent course material from draining through the weephole and into the channel.

yielding

the maximum limit state the reinforcing steel is intended to resist in the design. Once the reinforcing steel goes beyond its yield limit, its structural performance is permanently degraded and altered.

STRUCTURAL INTEGRITY STUDY
PERMANENTE CREEK PLANNING STUDY LOCATED IN SANTA CLARA COUNTY, CALIFORNIA

1.0 INTRODUCTION

This report presents the study process and results of the *Structural Integrity Study* (Study), part of the Santa Clara Valley Water District's (District) comprehensive *"Permanente Creek Planning Study located in Santa Clara County, California"* (Planning Study). The Study was conducted by Biggs Cardosa Associates, Inc. (BCA), and included a structural and geotechnical engineering investigation of concrete channel facilities along Permanente and Hale Creeks from the upstream end of the Cargill Salt Ponds to Foothill Expressway, including the Permanente Diversion. Three types of concrete channel facilities occur in the project alignment and were the subjects of this Study: 1) trapezoidal channels, 2) vertical walled channels (also known as U-frame channels), and 3) box culverts. Figure 1 (*Project Vicinity Map*) shows the project alignment located in the cities of Los Altos and Mountain View.

This Introduction includes a discussion of the purpose and objectives of the Study and report, the project background and scope, and the report format and organization.

1.1 Purpose and Objectives

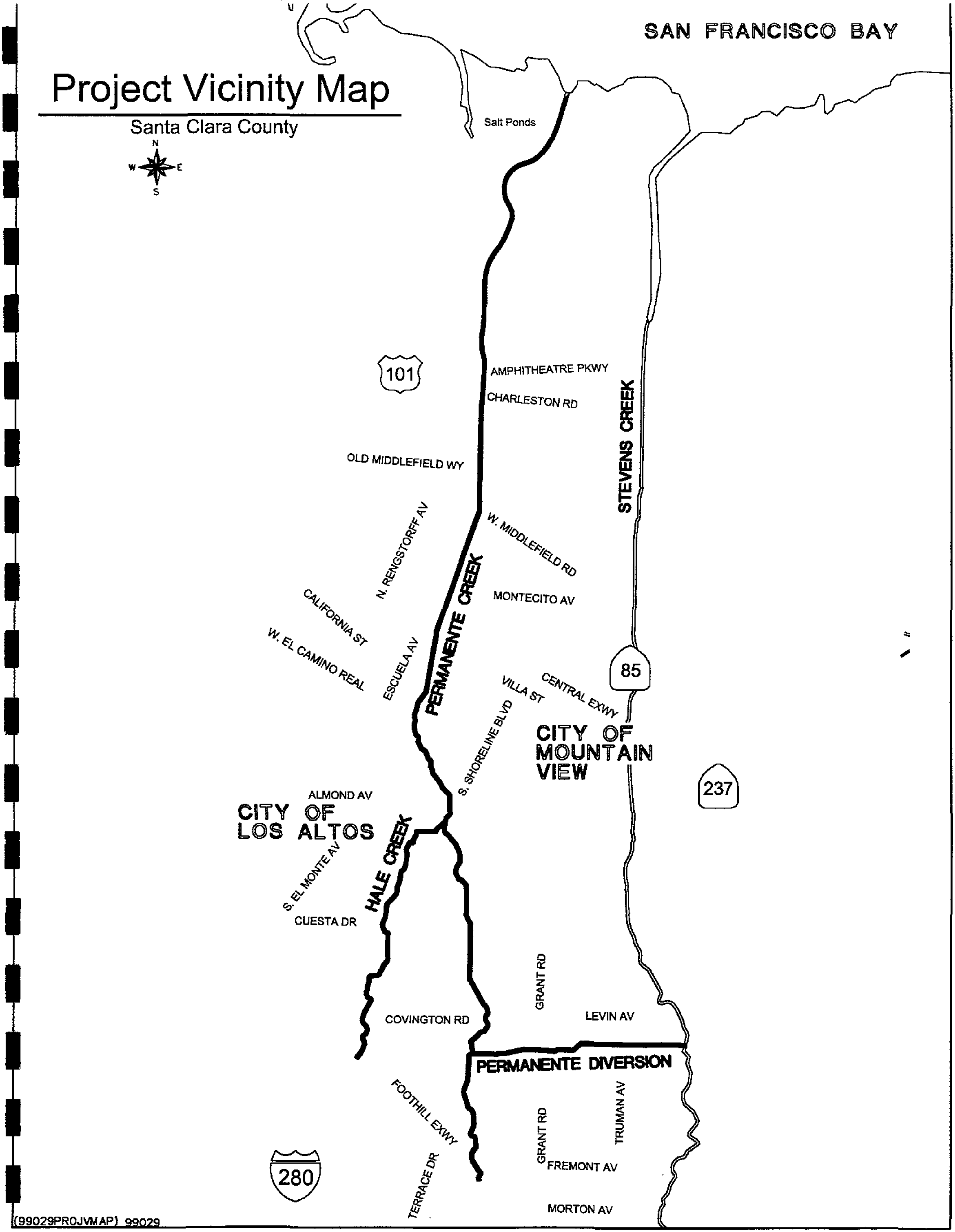
The purpose of this report is to present the results and recommendations of the Study to the District. The information presented in this report will be used to assist the District in: 1) prioritizing recommended channel repair and replacement work, and 2) estimating associated costs along the Permanente and Hale Creek alignments. General conclusions developed for the studied alignment (such as deficiency patterns found, remaining life expectancy, type of rehabilitation and associated costs) may be used in the future to prioritize work for similar facilities in the District's other creek alignments. In addition, the results of the Study were used to develop design recommendations and estimated costs for construction of future channel facilities the District may consider.

Specifically, the purpose of the Study was to:

1. Evaluate the current structural and geotechnical condition of the channels and their original design and construction,
2. Determine the underlying causes of any deficiencies found,
3. Estimate the remaining life of the channels, and
4. Develop recommendations for potential remedial and replacement measures, maintenance and monitoring programs to address any deficiencies found.

Project Vicinity Map

Santa Clara County



The overall scope of the Study included the following:

- Analyze the as-built construction to verify the structural adequacy of the design based on current design codes,
- Identify existing deficiencies and failures and their possible causes,
- Document the current condition and 'rate' the condition of the existing concrete channels,
- Estimate the remaining life expectancy, functional adequacy, durability, and overall stability of the facilities,
- Prioritize recommendations for maintenance and rehabilitation of damaged areas in terms of a short-term and long-term maintenance program to ensure flood management system performance reliability, and
- Identify a long-term inspection program.

1.2 Project Background

The Planning Study is investigating flooding, erosion, sedimentation, and maintenance problems on Permanente Creek, the Permanente Diversion, and Hale Creek. The Planning Study limit is from the San Francisco Bay to Foothill Expressway. The objective of the Planning Study is to develop a plan that reduces the potential for flood damage, reduces erosion and sedimentation, reduces maintenance costs, and protects fish and wildlife habitats and environmental resources of the creeks as a whole.

During the Planning Study investigation, the District's Maintenance Department observed significant deterioration of the concrete channels along portions of the Permanente and Hale Creek alignments, two of the District's oldest facilities constructed in the 1960s. Such deterioration had not been identified before within the District and included:

- Concrete walls that were cracked and required bracing,
- Steel reinforcing bars that were completely rusted through, and
- Ground settlement behind weepholes that were no longer functioning.

Because the age and condition of the channels could potentially affect the long-term function of the facility, the District decided to study the entire structural alignment, including Permanente Creek, Permanente Diversion, and Hale Creek. The Structural Integrity Study summarized herein is therefore included as an adjunct to the ongoing Planning Study and was designed to address the following questions and concerns:

- Why is the deterioration occurring?

- How common is this type of channel structure deterioration in other parts of California and the country in general?

- What is the estimated remaining life expectancy of the facilities?

- How can the facilities be repaired and maintained and what are the associated costs?

1.3 Scope of Study

The scope of the Study included investigation, assessment, and evaluation of all 32 reaches of the Permanente and Hale Creeks and Permanente Diversion alignments. These alignments total 9,339 meters (5.8 miles) long with some portions of the project alignment consisting of unimproved (non-concrete) channels, levees and bridges. The bridges, which fall under the City of Mountain View's jurisdiction and the part of Permanente Creek which is levee (Reaches 1 to 13), were investigated separately. The levee report, *Geotechnical Investigation Report, Permanente Creek Levee Evaluation, Santa Clara County, California, February 2000*, is provided as Supplement 1 to this report. The bridges which fall under the City of Mountain View's jurisdiction were also investigated separately and are addressed in the report *Structural Review and Inspection of City Bridges and Culverts, City of Mountain View Department of Public Works, November 1995*. Newer portions of the alignment rehabilitated in the 1980s were also included in the scope of work because it was valuable to compare their design and condition to that of the older structures when developing theories regarding the causes of excessive wall deflections.

8,200 meters (5.1 miles) of concrete channel facilities were investigated, at an average length of 256 meters (841 feet) per reach. The reaches varied in length from as short as 53 meters (174 feet) at Reach P13B to as long as 1152 meters (3,780 feet) at Reach PD2. The reach numbers and descriptions are presented in Table 1 *(District Reach No. Descriptions)*.

The three creek distinctions in the project alignment of this Study include:

- Permanente Creek (Reaches 14 to 73),

- Hale Creek (Reaches 43 to 55), and

- Permanente Diversion (Reaches 51 to 71)

Table 1 - District Reach Number Descriptions

Creek	District Reach No.	Beginning Reach Location	*	Ending Reach Location	Channel Type	Construction Date	Remaining Life (Years)
Perm	P 1	Sta. 0+00	to (d/s)	North Shoreline Blvd.	earth fill levee	1960	See Levee Report
Perm	P 2	North Shoreline Blvd.	to (d/s)	Amphitheater Parkway	earth fill levee	1960	See Levee Report
Perm	P 3	Amphitheater Parkway	to (d/s)	Charleston Road	earth fill levee	1960	See Levee Report
Perm	P 4	Charleston Road	to (d/s)	Highway 101	earth levee/concrete trapezoidal	1960	5-10
Perm	P 5	Highway 101	to (d/s)	Old Middlefield Way	vertical walled	1967	10-15 (vertical walled Only) 20-25 (Box culvert)
Perm	P 6	Old Middlefield Way	to (d/s)	Rock St.	vertical walled	1967	10-15 (vertical walled Only) 20-25 (Box culvert)
Perm	P 7	Rock St.	to (d/s)	Middlefield Parkway	vertical walled	1967	10-15 (vertical walled Only) 20-25 (Box culvert)
Perm	P 8A	Middlefield Parkway	to (d/s)	San Ramone Ave.	vertical walled	1967	10-15 (vertical walled Only) 20-25 (Box culvert)
Perm	P 8B	San Ramone Ave.	to (d/s)	San Luis Ave.	vertical walled	1967	5-10 (vertical walled Only) 20-25 (Box culvert)
Perm	P 9	San Luis Ave.	to (d/s)	Montecito Ave.	vertical walled	1967	5-10 (vertical walled Only) 20-25 (Box culvert)
Perm	P 10	Montecito Ave.	to (d/s)	Hackett Ave.	vertical walled	1967	5-10 (vertical walled Only) 20-25 (Box culvert)
Perm	P 11A	Hackett Ave.	to (d/s)	Hetch-Hetchy	vertical walled	1967	5-10 (vertical walled Only) 20-25 (Box culvert)
Perm	P 11B	Hetch-Hetchy	to (d/s)	SPRR/Central Expressway	vertical walled	1967	5-10 (vertical walled Only) 20-25 (Box culvert)
Perm	P 12	SPRR/Central Expressway	to (u/s)	Villa St. culvert	vertical walled	1967	5-10
Perm	P 13A	u/s Villa St. culvert	to (d/s)	Villa St. culvert	culvert	1963-1964	20-25
Perm	P 13B	d/s Villa St. culvert	to (u/s)	California/El Camino culvert	concrete trapezoidal	1958	15-20
Perm	P 14	u/s California/El Camino culvert	to (d/s)	California/El Camino culvert	culvert	1958/1962/1963/1964**	20-25
Perm	P 15A	d/s California/El Camino culvert	to (d/s)	Park Drive	culvert	1962	5-10 (vertical walled Only) 20-25 (Box culvert)
Perm	P 15B	Park Drive	to (d/s)	Mt. View Ave.	culvert/vertical walled	1962	0-5 (vertical walled Only) 20-25 (Box culvert)
Perm	P 16	Mt. View Ave.	to	Hale Creek Confluence	vertical walled	1962	5-10 (vertical walled Only) 20-25 (Box culvert)
Perm	P 17	Hale Creek Confluence	to (d/s)	Marilyn Dr.	unimproved earth	N/A	N/A
Perm	P 18	Marilyn Dr.	to (d/s)	Barbara Ave.	unimproved earth	N/A	N/A
Perm	P 19	Barbara Ave.	to (d/s)	Miramonte/Cuesta culvert	unimproved earth	N/A	N/A
Perm	P 20	Miramonte/Cuesta culvert	to (d/s)	St. Francis HS (Entrance-u/s most d/w)	culvert/unimproved earth/sacked concrete	1959 (Culvert), N/A (Unimproved earth)	10-15 (Culvert), N/A (Unimproved earth)
Perm	P 21	St. Francis HS (Entrance-u/s most d/w)	to (d/s)	Covington Rd.	unimproved earth/sacked concrete	N/A	N/A
Perm	P 22	Covington Rd.	to (d/s)	54' pipe at Eastwood	unimproved earth/sacked concrete	N/A	N/A
Perm	P 23	54' pipe at Eastwood	to (d/s)	Portland Ave.	concrete trapezoidal/sacked concrete trapezoidal	1981	35-40 (Trap. Channel only) 20-25 (Box Culvert)

Creek	District Reach No.	Beginning Reach Location	*	Ending Reach Location	Channel Type	Construction Date	Remaining Life (Years)
Hale	H 1A	Permanente Creek Confluence	to (d/s)	Mountain View Ave.	concrete trapezoidal	1960	15-20
Hale	H 1B	Mountain View Ave.	to (d/s)	Arroyo Rd.	concrete trapezoidal	1960	15-20 (Trap. Channel only) 20-25 (Box Culvert)
Hale	H 2A	Arroyo Rd.	to (d/s)	Marilyn Dr.	concrete trapezoidal	1960	5-10 (Trap. Channel only) 20-25 (Box Culvert)
Hale	H 2B	Marilyn Dr.	to (d/s)	Sunshine Dr. (north)	concrete trapezoidal	1960	5-10 (Trap. Channel only) 20-25 (Box Culvert)
Hale	H 3A	Sunshine Dr. (north)	to (d/s)	Sunshine Dr. (south)	concrete trapezoidal	1960	5-10 (Trap. Channel only) 20-25 (Box Culvert)
Hale	H 3B	Sunshine Dr. (south)	to (d/s)	Springer Rd.	concrete trapezoidal	1960	5-10 (Trap. Channel only) 20-25 (Box Culvert)
Hale	H 4	Springer Rd.	to (d/s)	Cuesta Dr.	concrete trapezoidal	1960	5-10 (Trap. Channel only) 20-25 (Box Culvert)
Hale	H 5A	Cuesta Dr.	to (d/s)	Arboleda Dr.	vertical walled	1960	5-10 (Trap. Channel only) 20-25 (Box Culvert)
Hale	H 5B	Arboleda Dr.	to (d/s)	Rosita Ave.	vertical walled	1960	0-5 (Vertical walled) 20-25 (Box Culvert)
Hale	H 6	Rosita Ave.	to (d/s)	Covington Rd.	Unimproved earth	N/A	N/A
Hale	H 7	Covington Rd.	to (d/s)	Foothill Expy.	Unimproved earth	N/A	N/A

Creek	District Reach No.	Beginning Reach Location	*	Ending Reach Location	Channel Type	Construction Date	Remaining Life (Years)
Perm Div	PD 1	Stevens Creek Confluence	to (d/s)	Dierickx Dr.	culvert/concrete trapezoidal	1959/1981**	5-10 (Trap. Channel only) 20-25 (Box Culvert)
Perm Div	PD 2	Dierickx Dr.	to (d/s)	Grant Rd.	Concrete trapezoidal	1959	5-10
Perm Div	PD 3	Grant Rd.	to (d/s)	Carmel Ter.	concrete trapezoidal/vertical walled	1959/1986**	15-20 (Vertical walled only) 5-10 (Trap. Channel)
Perm Div	PD 4	Carmel Ter.	to (d/s)	Permanente Creek Confluence	vertical walled/concrete trapezoidal	1959/1986**	5-10 (Trap. Channel only) 15-20 (vertical walled)

* Note: Limits for reaches are to the downstream (d/s) end of the structures, unless otherwise noted, such as at box culverts.

** For extents of construction dates, see maps

1.4 Report Organization

This report is organized as follows:

Section 1 - Introduction
Introduces the purpose and objectives, background and scope of the Study.

Section 2 - Study Approach and Methodology
Provides an overview of how the Study was designed, the rationale for investigating the channels, and the results of comparative research of similar facilities.

Section 3 - Study Findings
Discusses the results of the channel structure evaluation including the data trends and their causes, and references the Site Investigation Summary Reports and deficiencies found in the structural integrity of the channels.

Section 4 - Conclusions and Recommendations
Describes the general condition of the facilities, the remaining channel life estimates, the applicable repair or replacement options, and the basis for associated cost estimates. Contains professional recommendations regarding which sections should be repaired or replaced, what maintenance and monitoring programs should be implemented, and what should be considered for future design and construction of channel facilities.

Appendices

- Technical data collected during the Study and referenced in this report are presented in Site Investigation Summary Reports and on Summary Maps in Appendices A and B.

- The levee report, photographs, forms, field documents, test results, logs of telephone surveys and Internet research, and quantity and cost data are included as Supplements to this report in a separate binder.

2.0 STUDY APPROACH AND METHODOLOGY

This section provides an overview of the approach to conducting the Study, which consisted of three-phases. It also includes a summary of procedures and tests conducted. The three phases of the Study are summarized below and described in more detail in the following sections. Technical terms are defined in the glossary provided in the front of this report.

Phase I - Existing Data Collection *- Collect and review available as-built plans and geologic reports for the channels as well as information from other municipalities regarding channel evaluation criteria.*
Data from the review provided a foundation for understanding how the structures were originally designed, constructed and supported by surrounding soils. In addition, research indicated channel structures of similar age in other municipalities were experiencing similar deterioration, but standard evaluation criteria had not yet been established. This information was used to develop channel structure evaluation criteria indicating what aspects of the channel structures needed to be studied further in Phase II.

Phase II - Site Investigation Program *- Conduct two field data gathering programs to gather further information on the channel structures: (1) A Visual Site Inspection Program, and (2) A Materials Testing Program.*
Comprehensive site inspections and material tests were conducted by a team of structural and geotechnical engineers to evaluate the condition of the channels. The visual site inspection included measuring the structures and observing physical evidence of deterioration such as cracks. The materials tests included measuring the strength of the concrete and checking for corrosive conditions. A summary of the procedures and tests conducted during Phase II is provided. The results of the field effort were used in Phase III to evaluate and recommend repairs or replacement of any deteriorated channel structures.

Phase III - Data Evaluation and Recommendation Process *- Evaluate data collected in Phases I and II and develop recommendations to address any structural deterioration found in the project alignment as well as design of future channel structures.*
A comprehensive evaluation of deterioration or "deficiency patterns" and their causes was conducted and recommendations were developed for repair or replacement. The recommendations included prioritization of which channel structures would require immediate attention and what type of remedial work would be required, as well as a long-term monitoring and maintenance program. Costs were estimated for each existing repair or replacement scenario for the deficiency patterns identified. The remedial approaches and associated costs were also applied to design recommendations for future channel work.

2.1 Phase I – Existing Data Collection

The Existing Data Collection Phase of this project included: 1) review of available as-built plans and reports to provide background data on the channels under study, and 2) developing channel structure evaluation criteria used to guide collection of further data to assess their current condition. The review of background data familiarized the team with the details and design of the existing channels and was used to identify what further data was needed to evaluate their condition.

2.1.1 Collection and Review of As-Built Plans and Reports

The team collected as-built plans for the channel structures in the project alignment, available soils and geologic literature, and aerial photographs at the beginning of the Study. These plans and reports were reviewed and files were created for the individual reaches of the studied alignment to consolidate valuable existing information on their design and the adjacent soil conditions. Data from the review was evaluated and provided a foundation for understanding how the structures were designed, constructed and supported by surrounding soils as follows:

- **As-Built Plans**
  Limits of the structure type (where each one begins and ends along the project alignment), details of design, date of construction, channel section geometry, concrete design strengths, and rebar grade, sizes, cover and placement.

- **Soils and Geologic Literature**
  Characteristics of soil supporting the structures.

- **Aerial Photographs**
  Limits of structure types and correlated the project metric stationing to the project alignment.

Additional information needed to determine the causes of deterioration included collecting data regarding the current condition of the channel structures. In order to collect current data in a methodical fashion and learn as much as possible about the current condition of the channels, evaluation criteria were developed to design the field investigation effort in Phase II.

2.1.2 Channel Structure Evaluation Criteria

As input to developing evaluation criteria for the channels, comprehensive telephone surveys were conducted with numerous county, state and federal agencies and information was researched on the Internet regarding the evaluation and condition of waterway infrastructure in the United States. The research was conducted to determine whether pre-existing evaluation criteria for channel structures were in use elsewhere in the nation. Results of the telephone surveys and Internet research are summarized below. The telephone surveys are further summarized in Table 2 (*Summary of Telephone Surveys*) and the records of telephone surveys and Internet research are provided as Supplement 2 to this report.

Table 2 - Summary of Telephone Surveys

Agency	Contact	Phone	Summary
Alameda County Flood Control	*John Tejano*	*510.670.5512*	*No formal review criteria. All lined channels built by County.*
APWA	***Stephanie Osborn***	*202.393.2792*	*No formal review criteria*
ASCE	*Brian Parsons, Water Resources Dept.*	*800.548.2723.4.6071*	*ASCE is not involved in review*
Contra Costa County Flood Control	*Dean Eckerson, Director* *Greg Connaughton, Maintenance* *Aileen Doten, Admin. Services*	*925.313.2271* *925.313.7002* *925.313.2305*	*No formal review criteria*
Fresno Irrigation District	***Thad Betner***	*555.233.7161x19*	*No formal review criteria*
Fresno Metropolitan Flood Control District and *State Association of Flood Control Agencies*	*Doug Harrison*	*559.456.3292*	*No formal review criteria*
Los Angeles County Department of Public Works	*Jim Noyes Chief Deputy Director* *Gary Hartley, Deputy Director* *Brian Sasaki Deputy Director Flood Maintenance* *Ken Erhard Assistant Deputy Director Flood Maintenance* *Richard Seidon, O&M*	*626.458.4002* *626.458.4008* *626.458.4145* *818.896.0594*	*No formal review criteria for structural condition. There are formal criteria for O&M. The County is currently reviewing its O&M procedures, and declined to disclose their current criteria. Channels greater than fifty years old have reached the end of their service life.*
Modesto Irrigation District	*Ed Tobias*	*209.526.7637*	*No formal review criteria*
San Diego County	*Kent Burnham*	*619.874.4084*	*No formal review criteria*
Santa Barbara County Flood Control	*Larry Faucet, Supervisor of O&M*	*805.568.3437*	*No formal review criteria. Channels originally built by the Soil Conservation Service are reaching the end of their service life.*
Ventura County Department of Public Works	*Hugh Clabaugh* *Kevin Keivanfar*	*805.654.2016* *805.654.2906*	*No formal review criteria. Trapezoidal channels were destroyed by the earthquake. They are being replaced by rectangular channels.*
US Army Corps of Engineers	*Jim Sander, Construction Operations*	*916.557.5275*	*No formal review criteria*
USDA – Natural Resource Conservation Service	*Charles Davis* *Bill Ward*	*530.792.5622* *530.792.5616*	*No formal review criteria. Local agencies write reports of reviews, and submit to NRCS.*

Telephone Surveys

Telephone surveys were conducted with personnel of County Flood Control Districts, Public Works Agencies, Civil Engineering Associations, Irrigation Districts, the Corps of Engineers, and the Natural Resource Conservation Service. These agencies where asked if they had any existing concrete channel evaluation criteria for their facilities, and if and what types of problems they may be encountering with their facilities. Based on survey responses, it appears this Structural Integrity Study for Permanente Creek is the first of its kind to formally evaluate and identify deficiency patterns and rehabilitation options for channel structures. The survey indicated there were no formal evaluation criteria currently under development or in use for channel structures.

Most agencies simply reconstructed the channel structure segments as their operation and maintenance personnel discovered the deteriorated channel segments or they received public complaints. They also indicated channels that were reaching the end of their 50 to 60 year life expectancies had substantial structural deterioration. The channel structures in the Permanente and Hale Creek alignments were originally built in the 1960s and are approximately 40 years old. Every facility has a limited life expectancy; when properly designed and constructed, the life span of the channel structures built in the 1960s is approximately 50 to 60 years. This was generally confirmed by comparing data from other cities and agencies whose facilities are also showing signs of significant deterioration as they near their life spans.

Internet Search

Given the empirical life span data of 50 to 60 years for the channels being studied, five Internet web sites were researched to determine if there was any statistical documentation of the life of concrete channel structures. These web sites included the US House of Representatives, the US Senate, National Research Council, American Public Works Association, and the web site address http://iti.acns.nwu.edu. The research concluded that there was no statistical documentation of the life of concrete channel structures. However, the government has acknowledged that over forty percent of the aging inland waterway systems have exceeded their 50-year design life and the waterway infrastructure in the United States is in need of rehabilitation. Consequently, the US government has passed several bills and authorized programs to help fund and benefit the rehabilitation of these waterways. Funds are expected to be available for the waterways infrastructure' rehabilitation and improvements throughout the next few years.

Criteria

After the surveys and research were conducted indicating no standards were available for evaluating channel structures, the team developed channel evaluation criteria that would be applied during two field data gathering programs: a Visual Site Inspection Program and a Materials Testing Program. These programs were designed to collect additional data regarding the current conditions of the channels and their structural integrity and are described in the following sections.

2.2 Phase II – Site Investigation Program

The goal of the Site Investigation Program was to assess the current channel conditions, test the structural and soil materials, and document the deterioration. A Site Inspection Procedure Guide (Supplement 3; *Site Inspection Program Documents*) was developed for performing an initial site assessment walk-through and several follow-up site-inspection and materials testing visits, which were conducted by a team of structural and geotechnical engineers to evaluate the current condition of the channels.

The Site Inspection Procedure Guide outlined a standardized visual inspection format that was used to eliminate judgmental variances between inspectors during the documentation of the visual assessment. It also included standard site inspection forms for documenting specific information such as geometric data, loading conditions, modification data, concrete condition, reinforcement condition, wall deformations, and soil and drainage conditions.

The initial site assessment walk-through was performed by a team of two or three engineers. The entire project alignment was walked over several days and each applicable form was completed for each segment of the studied alignment. Pictures were also taken and logged for future reference (Supplement 4*: Photograph Log and Album*).

Several follow-up site inspection visits were performed as required to verify theories and conclusions and to collect additional information required during the analysis phase. Site-testing visits were performed by the geotechnical engineers, and testing companies were procured to obtain soil and concrete samples and perform specific tests such as Ground Radar Penetration (GPR) tests, Pacometer tests, Half-Cell Potential tests, and sounding tests.

Inspection results were documented on Site Inspection Forms (Supplement 3; *Site Inspection Program Documents*) and corresponding Photo Logs (Supplement 4). The Site Inspection Forms and Materials Testing Reports were compiled and became the foundation of the Site Investigation Summary Reports presented in Appendix A. The originals are presented in (Supplements 5 and 6; *Completed Site Inspection Forms and Materials Testing Reports*). The condition of the channel structures along the project alignment were also graphically summarized and plotted on Summary Maps presented in Appendix B.

The layout and components of the Site Investigation Summary Reports used during the Field Investigation effort are described below.

2.2.1 Site Investigation Summary Reports

Site Investigation Summary Reports were prepared for each of the 32 reaches included in the Study and are presented in Appendix A. These reports provide a log of all data collected for the reach identified and are divided into five categories:

1. **General Information** - Basic data for the reach such as the creek name, the reach number and location, the channel type, the original date of construction and the date of the inspection.

2. **General Dimensions** - Dimensions of the reach such as the channel height, the channel width at the top and at the bottom, and the left and right channel side slopes.

3. **General Condition of the Reach** - Five standard concerns are listed such as concrete cracks, surface defects, exposed reinforcement, structural deformation, and soil stability. Additional space was provided for any other concerns, and the overall condition of the reach as it pertains to each respective concern is noted under the general remarks section.

4. **General Condition of the Channel for Future Structural Repair/Modification** - If a reach did not have any existing structural repairs or modifications, any spatial limitations or concerns that may effect the future rehabilitation of the existing channel would be listed. Examples of this would be fence lines, utilities and heavy vegetation., **or**

   General Condition of the Existing Structural Repairs/Modifications - If a reach had an existing structural repair or modification, any as-built structural repair/modifications and the year in which it was constructed would be listed. Any spatial limitations or concerns that may effect any future rehabilitation of the channel would also be noted.

5. **Summary and Conclusions** - The Summary of Investigation subsection provides a synopsis of what deficiencies were encountered during the field visit and their possible explanations. Conclusions, recommendations and structural life expectancy for the reach are listed in the Conclusions and Recommendations subsection.

The two components of the Field Investigation Phase of work are described in the following sections.

2.2.2 Visual Site Inspections

The purposes of the Visual Site Inspections were to:

1. Gather general information on the reach such as the creek name, the reach location and number, the channel type, and the original date of construction,

2. Assess the dimensions of the reach such as the channel height, the channel width at the top and at the bottom, and the left and right channel side slopes, and

3. Evaluate the presence of concrete cracks, surface defects, exposed reinforcement, structural deformation, and soil stability.

A Site Inspection Procedures Guide, inspection forms, and an equipment checklist for the Visual Site Inspection Program are provided as Supplement 3 to this report.

2.2.3 Materials Testing

The purpose of the Materials Testing was to:

1. Evaluate the general soil conditions along the studied alignment,

2. Determine the engineering properties of the subsurface soils (including soil and groundwater corrosivity),

3. Evaluate the general condition of the concrete channel facility from a geotechnical standpoint,

4. Estimate the compressive strength of concrete forming the channel facility,

5. Verify the concrete channel reinforcement detailing,

6. Evaluate the channel invert support conditions, and

7. Evaluate the extent of corrosion.

The Materials Testing Program included:

- Performing the following field tests: Ground Penetration Radar (GPR) Test, Schmidt Hammer Tests, Pacometer Tests, and Half Cell Potential Tests,

- Obtaining concrete core samples from the concrete channel facility,

- Drilling and logging ten borings located along the project alignment,

- Laboratory testing of concrete cores and soil samples collected form the borings, and

- Analysis of field and laboratory data.

Results and test data from the Materials Testing Program field effort are provided in Supplement 6 to this report.

2.2.3.1 Summary of Materials Tests

Materials testing was performed to estimate the strength of the concrete in the channel facility; determine the size, spacing and cover for the lining reinforcement; evaluate the condition of the reinforcement form a corrosion standpoint; and evaluate hollows or cavities under the invert slab and behind the concrete channel facility.

The following tests were performed for the project:

1. **Ground Penetration Radar (GPR)** - This test was performed to evaluate the hollows and cavities under the channel invert slabs. The GPR tests were performed continuously along the bottom of the channel. GPR tests could not be performed along the bottom of the Permanente Diversion structure due to the presence of accumulated debris. The details of test locations are presented in the report prepared by Norcal Geophysical Consultants in Supplement 6 to this report *(Materials Testing Reports)*.

2. **Pacometer Test** – Pacometer tests were performed to determine the size, spacing and cover of the concrete channel structure reinforcement. The test results were also used to estimate the concrete core location and size. The Pacometer tests were performed at approximately 300 meter (984 foot) spacings. Additional tests were also performed at locations identified

by the structural engineer. The tests were performed on both the vertical walled channels and the trapezoidal channel linings.

3. **Concrete Strength Tests** – The strength of the lined concrete was primarily estimated by the Schmidt Hammer tests. The Schmidt test results were verified and correlated to the laboratory compressive strength results obtained on the concrete core samples. The Schmidt Hammer tests were performed along the channel at approximately 50 meter (164 foot) spacings. Concrete cores were obtained from the trapezoidal channel lining at approximately 300 meter (984 foot) spacings and at additional locations as requested by the structural engineer.

4. **Half-Cell Potential Tests** – Half-Cell Potential tests were performed on the trapezoidal channel lining reinforcement to evaluate the condition of the reinforcing with respect to corrosion. A total of ten Half-Cell Potential Tests were performed along the project alignment. The locations for the tests were decided by the project structural engineer, based on the defects data obtained during field visits. These locations are presented in the report prepared by Villalobos and Associates in Supplement 6 to this report (*Materials Testing Reports*). Conclusions resulting from the Half-Cell Potential Test were limited to the corrosion occurring in the exposed face reinforcing only and could only provide a general extrapolated understanding of the extent of corrosion. In retrospect, another corrosion test called an Impact-Echo Test would have been more beneficial. Future testing should implement the Impact-Echo Tests rather than the Half-Cell Potential Test.

5. **Sounding** – The channel walls were sounded with a steel hammer or a wooden mallet to determine the presence of cavities or hollows behind the walls or within the walls.

The following general procedures were followed for the tests performed:

1. **Ground Penetration Radar Tests** - These tests were performed by Norcal Geophysical Consultants, Inc. The general procedures used to perform the tests are presented in Supplement 6 to this report (*Materials Testing Reports*).

2. **Pacometer Tests** - The tests were performed using the HR-Rebar Locator (Model No. HR-7000) manufactured by NDT James Instruments, Inc. The Pacometer generates a magnetic field and measures any change due to the presence of magnetic material such as steel reinforcing. The magnitude of this change is indicated on the instrument meter, which has been calibrated to read directly in bar size and the distance from the base of the instrument. Details for reinforcement in both the directions were measured using the procedures outlined in the manufacturers guide. The results were verified by comparing with the details of the already exposed reinforcing and those exposed during coring. The Pacometer Tests results were also verified by comparing with the available as-built information.

3. **Concrete Strength Tests** - The Schmidt hammer tests were performed to evaluate the strength of the concrete used to construct the concrete channel facility. The concrete strengths were measured using the ELE International's Mechanical Concrete Test Hammer (Model CT-20A). The concrete test hammer works on the principles which are based on the rebound impact of a hammer on a piston which rests against the surface of the concrete; the greater the resistance of concrete, the greater the rebound impact. By reading this impact on

a scale and relating it to the concrete compressive strength curve developed for the Study (Supplement 6; *Materials Testing Reports*), the strength of concrete can be found. With the aid of the test hammer, the quality of concrete can be quickly examined along most of the project alignment. The tests were performed as per the procedure outlined in the manufacturers guide.

4. **Concrete Core Compression Tests** - Concrete cores were obtained from the concrete channel facility to develop the Schmidt Hammer reading versus Concrete Strength curve. The concrete core diameter was decided based on the rebar spacing, wall thickness, and available core sizes. Cores collected from the field were logged and observed for concrete defects such as honeycombing, segregation, etc. The concrete cores were also observed for the type, size and condition of the aggregate used to manufacture the concrete. Cores with length to diameter ratio of more than or equal to 2 were tested for concrete compressive strength as per test method ASTM C-42. The concrete compressive strength test results are presented in Supplement 6 to this report (*Materials Testing Reports*). The concrete core compression test results in conjunction with the Schmidt Hammer readings were used to develop the Schmidt Hammer reading versus Concrete Strength curve. This curve is also presented in Supplement 6 to this report (*Materials Testing Reports*). The holes resulting from coring were backfilled with cement grout.

5. **Half-Cell Potential Tests** - These tests were performed by Villalobos and Associates. The general procedure used to perform the tests are presented in Supplement 6 of this report (*Materials Testing Reports*).

6. **Sounding** - Sounding was performed at various locations along the channel walls to identify locations with corrosion, spalling, caving or other problems. The cavities and hollows behind the walls were also probed through the weepholes and from top of the walls (where accessible) with a steel probe. The sounding results were generally used to identify the locations for Half-Cell Potential tests.

2.2.3.2 Summary of Subsurface Investigation and Laboratory Testing

Based on the available boring logs and discussions with the project structural engineer, ten borings were drilled along the project alignment up to a depth of 6.6 meters (21.7 feet). Approximate locations of these borings are shown on the Test Result Map (Appendix B; *Summary Maps*). Bulk soil samples were also obtained from the weepholes for corrosion testing.

The test borings were advanced with a truck-mounted drill rig using a 200 millimeter (8-inch) diameter hollow stem auger. Selected drive samples were obtained from the borings at various depths using a 64-millimeter (2.5-inch) inner diameter (I.D.) Modified California Sampler or a 35-millimeter (1.3-inch) I.D. Standard Penetration Sampler. The sampler was driven into the subsurface soils under the impact of a 63.5-kilogram (140 pound) hammer having a free fall of 0.76 meters (2.5 feet). The blow counts required to drive the sampler for the last 0.3-meter (1 foot) are represented on the boring logs in Supplement 6 (*Materials Testing Reports*). The soil samples obtained during drilling were visually classified in the field and then transported to the laboratory for further evaluation and testing.

Laboratory tests were performed on selected samples obtained during field exploration to determine the physical and engineering properties of the subsoil (soil behind the structures). Laboratory tests included Moisture Content Tests, Dry Density Tests, Sieve Analysis, Atterberg Limit Tests, and Unconfined Compression Tests. These test results are summarized on the boring logs in Supplement 6 . Tests were performed as per the latest edition of ASTM standards. Corrosion tests including soils resistivity tests, pH, sulfate content and chloride content tests were performed on the bulk samples collected from the weepholes. The pH and soil resistivity tests were performed as per California Test Method T643. The sulfate and chloride content tests were as per California Test Methods T417 and T422, respectively. The corrosion test results are also summarized in Supplement 6.

Information obtained from a previous field investigation (Soil Engineering Services – Proposed Improvement of Permanente Creek, Mountain View, California, by Cooper & Clark Consulting Engineers, dated December 6, 1961) were used to supplement this Study. Relevant soils information from this Study are also included in Supplement 6.

2.2.3.3 Additional Testing

A more intensive investigation of the condition of the studied alignment included assigning specific tests to precise locations on the project alignment. Coring and half-cell potential tests were performed at locations where excessive wall deflections, vertical temperature expansion and contraction cracks in walls and longitudinal cracking of the invert were of concern. Data regarding the quality and condition of the concrete and reinforcement are essential in determining the condition of the channel at those locations.

Half-cell potential tests were performed at locations of exposed reinforcement to determine their rate of corrosion. Sounding was performed at places where voids were believed to be behind the channel wall or lining. The concrete cover was determined, recorded and compared to the as-built plans at each coring location.

2.3 Phase III – Data Evaluation and Recommendation Process

The Data Evaluation and Recommendation Process phase of the Study included a comprehensive evaluation of deterioration patterns, formulation of the causes of the deficiencies and recommendations for repair.

2.3.1 Data Evaluation

The following steps outline the process of how the data was collected and evaluated:

- The site inspection reports were completed and photographs were taken while performing site investigation walk-throughs.

- The information from the site inspection reports and the photographs were transferred to maps. The locations of all cracks, surface defects, exposed reinforcing and structural deformation were indicated on the maps.

- Engineers examined the as-built plans, maps and photographs looking for deficiency patterns and evaluated if there was a correlation to a particular channel type or construction date.

- Engineers evaluated whether the deficiencies found were detrimental to the overall structural integrity of the channel or were expected wear and tear of the channel during its service life.

- The extent and severity of each deficiency for each reach was summarized on the Summary Report of Site Investigation.

- Using the Summary Report for each reach in conjunction with the As-Built Analysis and Methodology for Estimating Remaining Channel Life, the structural life expectancy for each reach was assigned.

- Engineers developed recommendations for repair alternatives and future channel designs. A channel inspection and maintenance program and cost estimates for existing channel segments were also developed to assist the District in deciding which channel segments are a priority and to estimate the cost-to-benefit ratio of repair or total replacement.

2.3.2 Recommendations Process

As-built plans and the results from the Site Investigation and Materials Testing Programs were evaluated to search for a probable cause(s) for each structural deficiency. Once the probable cause(s) for each structural deficiency was identified, the design methodologies to prevent such deficiencies from reoccurring in future designs were reexamined and amended. The basis for the recommendations are presented in the following sections.

3.0 STUDY FINDINGS

This section summarizes the results of the evaluation performed on the data collected and the relevant findings. It includes a discussion of data trends and their causes, a description of the Summary Maps, and a summary of findings for the Site Investigation Program and As-Built Analysis for Estimating Remaining Channel Life. The section is organized as follows:

Data Trends and Causes
The evaluation identified three types of channel structures and seven general patterns of deterioration that were observed along the project alignment. The types of channels, causes for the deficiency patterns and their frequency and location along the project alignment are discussed. Details of the deficiency patterns are shown on Figures 2 through 8 (*Section 3.1.2*) and the locations are shown on the Summary Maps (Appendix B).

Summary Maps
Descriptions of six Summary Maps (Appendix B; *Summary Maps*) that show where different types of deterioration were observed along the project alignment are summarized: 1) Concrete Cracking, 2) Surface Defect, 3) Exposed Reinforcement, 4) Structural Deformation, 5) Test Result, and 6) Deficiency Pattern. The Deficiency Pattern Summary Map shows the locations where the seven types of deficiencies occur along the project alignment.

Site Investigation Findings
Results of the Site Inspection and Materials Testing portions of the Study are summarized, including project alignment conditions and locations, interpretations of subsurface and groundwater conditions, and a discussion of findings. Observations, test results and data are provided in supplements to this report.

As-Built Analysis and Methodology for Estimating Remaining Channel Life
In conjunction with the results of the Site Investigation, the As-Built Analysis used existing data and engineering judgement to determine the estimated structural life expectancies of the reach.

3.1 Data Trends and Causes

The Existing Data Collection Phase indicated there were three types of concrete channels found in the studied alignment and seven types of deterioration. These findings are summarized below:

3.1.1 Summary of Channel Types

The following three types of channels occur in the project alignment studied:

- **Trapezoidal Channels**
  There are six typical trapezoidal channel segments found within the studied alignment; three are in Permanente Creek, one in Hale Creek, and two in the Permanente Diversion.
  Often referred to as concrete channel linings or concrete-lined channels, they usually consist of a thin 100 to 150 millimeter (4 to 6 inch) "lining" of concrete with a nominal mat of welded wire fabric as reinforcing and have sloped sides and an invert slab. This mat of reinforcing is usually placed in the middle of the slab or lining and thus the concrete cover is a little less than half the thickness of the lining. The distance from the face of concrete to the

reinforcing steel is called the concrete cover. The concrete trapezoidal channel side slopes take minimal lateral earth loads because typically they are sloped at a 1:1 ratio or gentler rather than vertical.

- **Vertical Walled Channels (also known as U-Frame Channels)**
  There are four vertical walled channel details found within the studied alignment; two in Permanente Creek, one in Hale Creek, and the other in the Permanente Diversion.
  These types of channels are thicker than the trapezoidal channels (usually about 12 inches thick) and have vertical walls and an invert slab (bottom). The walls typically cantilever from the base and resist the lateral earth loads. These walls have two layers of reinforcing a few inches from the front and back surfaces of the wall and slab. The distance from the face of concrete to the reinforcing steel is called the concrete cover.

- **Box Culverts**
  There are four box culvert segments found within the studied alignment; three in Permanente Creek, none in Hale Creek, and one in the Permanente Diversion.
  These facilities are typically below ground (buried rather than open air channels) and are used to run under roads and driveways. The structure cross section resembles a "box cross section" or square and consists of a bottom invert slab, side vertical walls, and top deck slab. Depending on the width of the channel, the box culvert section can also consist of interior divider walls forming either one or multiple cells (square sections).

3.1.2 Summary of Deficiency Types

Based on the Existing Data Collection, Field Investigation, and Data Evaluation and Recommendation phases of the Study, seven different types of deterioration or "deficiency patterns" in the channels investigated were identified. Deficiency pattern descriptions and the locations where they occurred are shown on the Summary Maps and are summarized on the Deficiency Pattern Summary Map found in Appendix B (*Summary Maps*); they are also listed for each reach in Table 4 (*Deficiency Patterns by Reach*). Table 4 appears at the end of this section (Section 3.1.2) on page 39.

The seven deficiency patterns are summarized below in order of concern, severity, and frequency; a more detailed description of their causes follow.

1. **Excessive Wall Deflections** – Reduced wall capacity leads to flexural cracks, excessive wall deflections and eventual collapse due to: 1) underestimated design loads, 2) insufficient bar development, 3) the presence of a construction joint at the base of the wall which allows moisture to corrode the main reinforcing steel, reducing the wall capacity.

2. **Longitudinal Cracking of the Invert** – Deterioration of the invert reinforcing leads to wall rotation and eventual collapse due to: 1) underestimated design loads, 2) insufficient extension of the flexural reinforcing component into the invert, which contributes to the flexural failure in the invert, formation of a longitudinal crack, and rotation of the wall. Moisture eventually penetrates through the crack, corroding the nominal invert reinforcing which is doweling the rotated wall portion to the invert slab preventing collapse.

3. **Trapezoidal Channel Lining Deterioration** – Horizontal flexural cracks in the middle of the wall are due to: 1) significant lateral earth pressure, and 2) the light reinforcing and thin wall sections specified in the as-built plans which were not designed for any significant lateral earth loads. Vertical cracks due to temperature expansion, allowing for corrosion and expansion of the reinforcing, eventually delaminating and spalling the channel face of the concrete lining.

4. **Vertical Temperature Expansion and Contraction Cracks in Walls** – Minimal longitudinal wall reinforcing and the channel structure geometry appears conducive to the formation of significant vertical temperature expansion cracking in the walls. These cracks in the channel structure, where water is often abundant, allow for moisture penetration, corrosion of the reinforcing, concrete efflorescence, weakening of the concrete section, and further wall cracking.

5. **Spillage of Backfill and Foundation Material Through Weepholes and Gaps** – Deterioration of the weephole screens due to weathering allows for the erosion of backfill and foundation material and formation of voids and sink holes at sandy type backfill locations. The loss of the screens also allows for weephole clogging and possible additional hydrostatic loads on the wall at clayey type backfill locations. Unaccounted additional hydrostatic wall pressure may lead to Deficiency Number 1 – Excessive Wall Deflections.

6. **Exposed Reinforcement Due to Lack of Concrete Cover** – Insufficient concrete cover due to poor construction quality control enables weathering to easily spall off portions of the concrete cover. The exposed reinforcing corrodes, expands and eventually further spalls more concrete cover.

7. **Wall Expansion Joint Deterioration** – Deterioration of the expansion joint material due to time and weathering causes a vertical gap in the wall, which enables sandy backfill material to sift through the wall and produce soil cavities and sinkholes. The gap also catches debris that over time abrades and spalls off the concrete at the joint, exposing and corroding the reinforcing and causing further spalling of the concrete. Seismic movements at the joint may also cause pounding and contribute to the spalled concrete or a larger gap opening.

The locations along the project alignment where each type of deficiency was observed and the factors contributing to the deficiencies in each area are described in the following sections. Table 3 provides a summary of which reaches were affected by each deficiency pattern (*Deficiency Pattern Summary*).

Table 3 – Deficiency Pattern Summary

Deficiency	Affected Reach (District Reach Number)	Affected Length (meters [feet])	% of Project Alignment Affected
Excessive Wall Deflections	P5, P6, P7, P8A, P8B, P9, P10, P11A, P11B, P12, P15A, P15B, P16, H5B	3005 [9858]	32%
Longitudinal Cracking of the Invert	H5B	222 [728]	2%
Trapezoidal Channel Lining Deterioration	P4, H2A, H2B, H3A, H3B, H4, H5A, PD1, PD2, PD3, PD4	2913 [9556]	31%
Vertical Temperature Expansion and Contraction Cracks in Walls	P5, P6, P7, P8A, P8B, P9, P10, P11A, P11B, P12, P15A, P15B, P16, H5B, PD3, PD4	2723 [8933]	29%
Spillage of Backfill and Foundation Material Through Weepholes and Gaps	P5, P6, P7, P8B, P9, H2A, H3A	711 [2332]	8%
Exposed Reinforcement Due to Lack of Concrete Cover	P14, P16, H1B, H2B, H3A, H3B, H4, H5A, H5B, P23	298 [978]	3%
Wall Expansion Joint Deterioration	Entire Investigated Alignment	9339 [30637]	100%

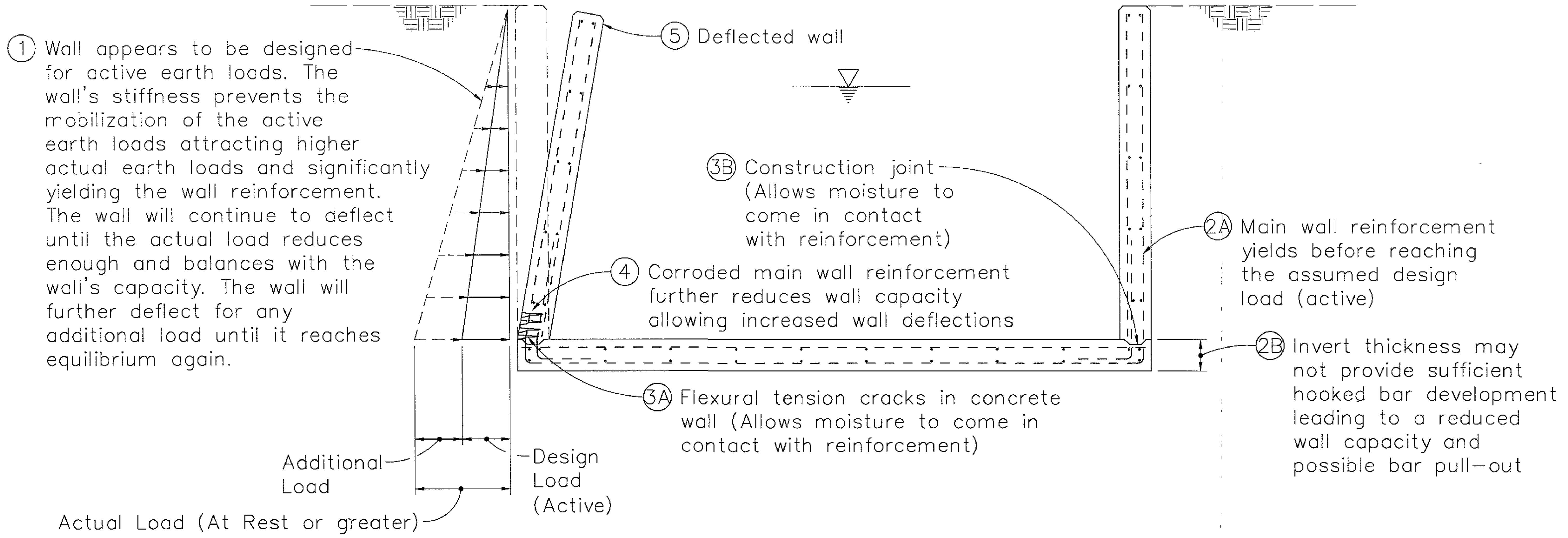
3.1.2.1 Deficiency #1 - Excessive Wall Deflections (Figure 2)

Excessive wall deflections were observed in many of the sections investigated for this Study, namely Reaches P 5 through P 12 and P 15A through P 16 of Permanente Creek, Reach H 5B of Hale Creek, and Reaches PD 3 and PD 4 of the Permanente Diversion.

Excessive wall deflections occurred only on vertical-walled channels where the walls were cantilevered from the invert slab. Various factors described below provide probable explanations of why excessive wall deflections have occurred along the project alignment.

General Cantilevered Wall Analysis

Several factors may be involved in excessive wall deflection of a cantilevered wall. Primarily, the wall may encounter more lateral pressures than assumed in the original design, which in turn leads to excessive wall deflections.



① Wall appears to be designed for active earth loads. The wall's stiffness prevents the mobilization of the active earth loads attracting higher actual earth loads and significantly yielding the wall reinforcement. The wall will continue to deflect until the actual load reduces enough and balances with the wall's capacity. The wall will further deflect for any additional load until it reaches equilibrium again.

⑤ Deflected wall

(3B) Construction joint (Allows moisture to come in contact with reinforcement)

(2A) Main wall reinforcement yields before reaching the assumed design load (active)

④ Corroded main wall reinforcement further reduces wall capacity allowing increased wall deflections

(2B) Invert thickness may not provide sufficient hooked bar development leading to a reduced wall capacity and possible bar pull-out

(3A) Flexural tension cracks in concrete wall (Allows moisture to come in contact with reinforcement)

SECTION

NTS

FIGURE 2

Note:

①, ②, ③, ... Indicates sequence of degradation activity

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PERMANENTE CREEK
FLOOD CONTROL PROJECT
STRUCTURAL INTEGRITY STUDY

DEFICIENCY #1
EXCESSIVE WALL
DEFLECTIONS

DESIGNED BY: DRD	DATE: 8/29/00
DRAWN BY: T. SIMMONS	SCALE: NONE
CHECKED BY: RLO	JOB No.: 99029
SHEET 22	
DRAWING No. A 029-2	REV. No.

Excessive wall deflections are primarily caused by in-situ lateral loads acting on a wall, which are higher than the lateral loads anticipated in the original design. For a cantilevered wall, an active lateral pressure distribution is typically assumed. This distribution, however, only acts on a vertical wall once the wall has sufficiently deflected. Due to the shearing resistance of the retained soil, the lateral earth pressure acting on the wall reduces from the higher at-rest lateral pressure to the active lateral pressure. The wall deflection required to attain the active lateral pressure is dependent upon the soil and the height of the wall.

Apparently, during the original design of the walls, the assumption was made that the walls resist the active lateral pressure distribution, which is not always valid. Wall restraint parameters and soil parameters such as soil type, degree of compaction, water content, and construction procedures, among others, are very influential in determining the actual lateral pressure on the wall. Minor variances in any of these soil parameters may significantly increase the actual lateral pressure beyond that of the assumed active lateral pressure.

The structural design details of the wall also dictate whether it is possible to attain the assumed active lateral pressure distribution before significantly yielding the wall reinforcement. The yielding of the wall reinforcement denotes the maximum limit state the reinforcement is intended to experience in design. Typically in reinforced concrete design, the yielding of reinforcement is reserved for temporary loads encountered during extreme events and not for the anticipated service loads. Once the reinforcement has yielded significantly, the behavior of the reinforcement is permanently degraded and altered. The steel material undergoes strain hardening, becomes increasingly brittle, and looses its ability to resume its preloaded strain and becomes inelastic.

Surcharge loading may also significantly increase the actual lateral pressure the wall resists. Examples of surcharge loading are increased levels of backfill or loads from adjacent structures or traffic.

Once a wall is exposed to lateral pressures that are higher than those originally intended, substantial flexure cracking occurs along the tension side of the wall. This cracking may lead to excessive wall deflections because the cracks allow detrimental elements like water to come in contact with the wall reinforcement and initiate corrosion. Corrosion of the main wall reinforcement can significantly increase wall deflections over time because corrosion reduces the cross sectional area of the reinforcement, which in turn reduces the structural capacity of the wall.

Excessive Wall Deflection Sequence of Events

For the excessive wall deflections that were observed along the project alignment during this Study, the following sequence of events has occurred or probably will eventually occur:

1. The original design underestimated the design lateral loads due to all or a combination of the factors previously stated. This causes tension cracking at the back face of the wall allowing for water intrusion.

2. Over time, the deterioration of the construction joint between the wall and invert of the vertical walled sections also allows for water permeation of the concrete section at the base of the wall.

3. Because the original design underestimated the design lateral loads, the higher wall moments required an increase in reinforcing development length. The as-built details reveal that the existing invert slab thickness may be insufficient to fully develop the main wall reinforcement. This lack of development length effectively reduces the capacity of the wall and promotes the cracking of the concrete at the base of wall/invert connection.

4. Water continues to permeate the concrete cracks, corroding the wall reinforcement.

5. The corroded reinforcement begins to weaken the rctaining capacity of the wall causing it to rotate and deflect excessively at the top.

6. Eventually the remaining main wall reinforcement will completely corrode causing the wall to rotate beyond the point of stability and collapse.

Site Specific Cantilevered Wall Analysis and Conclusions

There are four vertical walled channel segments found within the studied alignment. Two are in Permanente Creek, one is in Hale Creek and the other is in the Permanente Diversion. The differences in the as-built details reveals why some vertical walled channel sections are more structurally sound than others. Analysis of the details within the Permanente Diversion vertical walled channels indicate the reason why these are the only walls on the alignment that have not deflected excessively.

The vertical walled channel in the Permanente Diversion is the best structurally designed and detailed section of the four and is also the most recently built (circa 1985). This section was apparently designed assuming the active lateral pressure distribution was acting on the walls. Analysis of the as-built details of the wall support that assumption; allowing the wall to deflect sufficiently enough to mobilize the active lateral pressure distribution before yielding the wall reinforcement. The required wall deflection to mobilize the active lateral pressure distribution for the soil retained was determined per criteria from the Department of the Navy Facilities Engineering Command, Foundations and Earth Structures Design Manual 7.2, dated May 1982.

The subtle differences between designing and detailing are explained as follows.

The theoretical design process determines general parameters and minimum requirements for designing the structure such as the concrete strength, the amount of steel required to account for flexure and the required embedment length. Details of the design typically are developed in a subsequent phase. These details will incorporate the requirements calculated in the design but also includes additional engineering judgement not mandated in the design and the code such as the direction of the embedment hooks (towards the joint or away from the joint). These judgement calls can have a significant impact on the integrity of the final construction. By designing and detailing the wall such that its yield deflection is greater than the deflection required by the soil to mobilize the active lateral pressure distribution, it ensures that the reinforcement will not yield for any anticipated service load. Proper design and details of the Permanente Diversion vertical walled channels are the reason why these are the only walls on the project alignment that have not deflected excessively.

Analysis of the as-built details for the 2.75 meter (9 foot) walls of the vertical walled section between Highway 101 and Villa Street in Permanente Creek revealed that the yield deflection was approximately 85% of that required to attain the active lateral earth pressure apparently assumed in the design. Such design details explain why these walls have deflected more than anticipated. It also reveals why these walls are not as severely deflected as some others along the studied alignment.

Analysis of the as-built the details for the 2.14 meter (7 foot) walls of the vertical walled section between El Camino Real and the Hale Creek confluence in Permanente Creek show the wall would achieve a yield deflection that was approximately 50% of that required to attain the active lateral earth pressure. With this type of design, the walls are resisting loads that are significantly higher than the loads expected. Such details explain why the shortest vertical walls along the studied alignment have deflected the greatest amount.

The walls for the vertical walled section in Hale Creek were apparently designed to resist more than the active lateral earth pressure. They were apparently designed to resist the at-rest pressure. Yet, excessive wall deflections still exist along this vertical walled section, even with this increased structural capacity.

The walls in Hale Creek are deflecting excessively because of poor detailing of the reinforcement in the invert slab (i.e., the design was adequate but some critical details were not addressed properly). The amount of reinforcement in the wall is capable of resisting the higher at-rest loads but the premature bar cut-off locations of that reinforcement carrying the moment from the wall into the invert slab is what is causing the excessive wall deflections. The poor detailing of the reinforcement in the invert slab caused a longitudinal crack in the invert. The cracking of the invert allows a point of rotation to occur causing the walls to deflect excessively. This poor detailing is explained more extensively in Deficiency Number 2 - Longitudinal Cracking of the Invert.

The following Soil Anchor Repair Evaluation discussion presents the findings of a particular channel segment (Reach P15B) previously rehabilitated by the District's maintenance and design departments. It is discussed here because it occurs in conjunction with the wall deflection deficiency.

Soil Anchor Repair Evaluation

The concrete walls of the vertical walled channel of Reach P 15B have undergone severe deflections, and had been repaired using helical Chance^{TM} anchors. The soil anchors were installed at approximately 840 millimeters (2.75feet) from the top of the wall. Walers (an element that evenly distributes the horizontal load from the anchor) made of steel channels were used to distribute the load imposed from the soil anchors onto the deflected wall. The soil anchors were installed into the retained soil at an angle of 30 to 45 degrees from the horizontal with a pretension lock-off force of 20 kilonewtons (4.5 kips or 4,500 pounds of force).

A structural and geotechnical review of the construction plans had revealed three possible deficiencies for this existing repair alternative, which may explain why continued wall deflections were apparently observed. The three reasons why the soil anchor repair may not have been an effective way of preventing the walls from future, further deflection, are as follows:

- **The soil anchors may not be sufficiently pretensioned.** To stop the cantilevered walls from deflecting further, pretensioning the soil anchors is essential. That pretensioning force must be greater than or equal to the lateral force acting on the deflected cantilevered wall. If the soil anchors are tightened with a correct amount of pretensioning force, the helical anchors and deflected vertical wall will be in equilibrium and no additional deflection will occur. With the given anchor spacing and only 20 kilonewtons (4.5 kips) per anchor, calculations indicate that the pretensioning force was insufficient to prevent the wall from further deflection. To determine the required soil anchor pretensioning force, a design lateral soil load and load distribution must be established preferably by a geotechnical engineer.

- **The soil anchors change the loading on the structural wall element.** By installing soil anchors on the deflected cantilevered wall, a new loading is imposed on the structural wall element, which was not anticipated in the original design. In the original wall design, the maximum moment occurred at the base of the wall. The main flexural reinforcement was placed at the back face, base of the wall to account for this moment. This is where the maximum tension was expected. Because there was no significant tension on the front face of the wall, the front face received only nominal temperature and shrinkage reinforcement. However, the soil anchors changed the wall loading, imposing positive moment (tension on the front face) on the wall. With the existing front face steel only being nominal temperature and shrinkage reinforcing, the new loading could theoretically yield the front face steel and crack the wall. Calculations indicate that with only 20 kilonewtons (4.5 kips) per anchor, the front face wall steel is theoretically satisfactory. However, the 20 kilonewtons (4.5 kips) per anchor was shown to be too small a pretension load to prevent further wall deflections and larger pretension loads would have to be checked. If the soil anchor load is too large, the soil anchor spacing could be reduced to reduce the soil anchor load and enable the existing front face wall steel to work.

- **The soil anchors may not be adequately anchored.** For soil anchors to be adequately anchored, two requirements must be satisfied. Those two requirements are as follows:

  --The failure wedge of the retained soil must be identified and the length of helical Chance™ anchor within the failure wedge should not be included in the soil anchor length.

  --The required soil anchor pretensioning force must be determined by using a revised lateral soil pressure distribution. The lateral soil pressure distribution should be determined by a geotechnical engineer. If the designer assumes a lateral soil pressure distribution that is less than the actual lateral soil pressure distribution acting on the cantilevered wall, then the pretensioning force will be insufficient and consequently not adequately anchored. Furthermore, the cantilevered wall will continue to deflect until the soil anchor and actual lateral soil pressure distribution acting on the wall are in equilibrium.

3.1.2.2 Deficiency #2 - Longitudinal Cracking of the Invert (Figure 3)

There is only one location along the investigated alignment that uses the detail of abruptly terminating the wall steel within the invert slab and consequently there is only one location where longitudinal cracking of the invert slab has taken place: Reach H 5B of Hale Creek.

For the longitudinal cracking of the invert observed along the project alignment for this Study, the following sequence of events has occurred or probably will eventually occur.

1. The as-built details reveal that the main flexural reinforcement is carried only 915 millimeters (3 feet) into the invert slab and then cut-off. No other reinforcement along the bottom of the invert is provided.

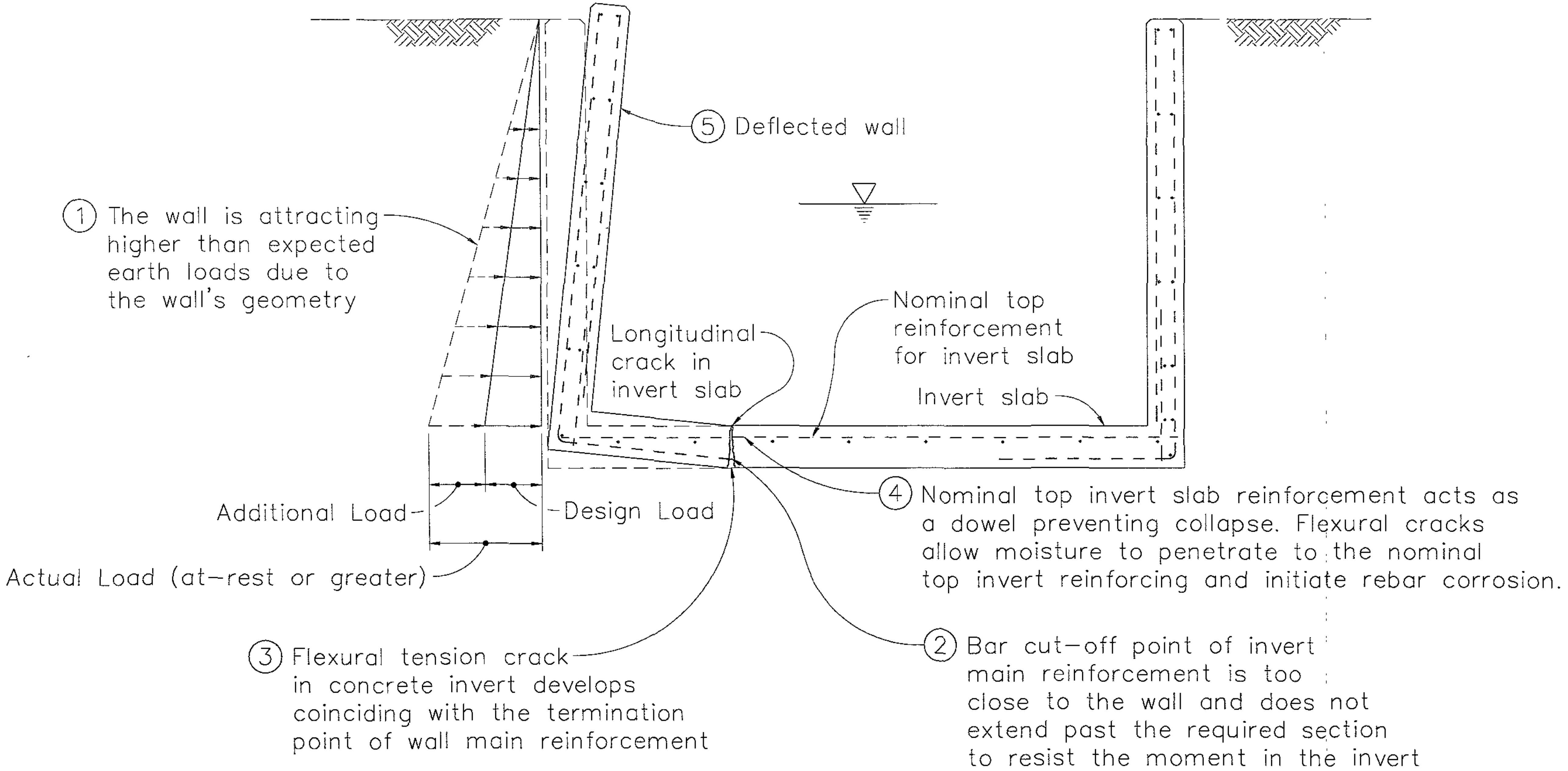
2. Although the original design apparently accounted for the at-rest lateral earth pressure distribution, greater than at-rest pressures must have been encountered in the channel section at some point in time. This caused a longitudinal flexure crack at the approximate location where the wall reinforcement terminated in the invert slab. The crack, which started from the bottom of the invert, propagated until it reached the top due to the lack of reinforcement along the bottom of the invert slab.

3. The longitudinal crack in the invert releases the rotational restraint at that location allowing the wall to rotate and deflect inward.

4. The remaining nominal invert steel is effectively doweling the rotated wall to the invert preventing its sheared release. Moisture will eventually penetrate through the flexural crack causing the remaining nominal invert steel to corrode.

5. When the remaining nominal invert steel completely corrodes, the wall will rotate further and possibly collapse.

The wall reinforcement for the vertical walled section in Hale Creek was hooked into the invert slab and terminated abruptly approximately 915 millimeters (3 feet) from the wall. Although the steel reinforcing was correctly placed along the bottom of the invert slab where tension is expected, no additional steel was placed from that point on along the bottom of the slab. The capacity of the slab at the location where the wall reinforcement was terminated is consequently, solely based on the tension capacity of the concrete. Detailing such as this is structurally very poor because without reinforcing, the flexural capacity of the invert slab is solely based on the tension capacity of the concrete. This type of detailing will lead to a sudden, brittle failure versus the structurally preferred ductile failures.


Longitudinal crack in invert slab
Nominal top reinforcement for invert slab
Invert slab
Additional Load
Design Load
Actual Load (at-rest or greater)

① The wall is attracting higher than expected earth loads due to the wall's geometry

② Bar cut-off point of invert main reinforcement is too close to the wall and does not extend past the required section to resist the moment in the invert

③ Flexural tension crack in concrete invert develops coinciding with the termination point of wall main reinforcement

④ Nominal top invert slab reinforcement acts as a dowel preventing collapse. Flexural cracks allow moisture to penetrate to the nominal top invert reinforcing and initiate rebar corrosion.

⑤ Deflected wall

SECTION
NTS

FIGURE 3

Note:
①, ②, ③, ... Indicates sequence of degradation activity

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PERMANENTE CREEK
FLOOD CONTROL PROJECT
STRUCTURAL INTEGRITY STUDY

DEFICIENCY #2
LONGITUDINAL CRACKING OF THE INVERT

DESIGNED BY: DRD	DATE: 8/29/00
DRAWN BY: T. SIMMONS	SCALE: NONE
CHECKED BY: RLO	JOB No: 99029
SHEET 28	
DRAWING No.	REV. No.
A 029-3	

The capacity of the invert slab based solely on the tension capacity of the concrete was theoretically greater than the demand on the invert slab at that location from the at-rest pressure. This implies that at some point in time the vertical walled channel was resisting loads that were greater than the at-rest pressure because concrete cracking had occurred. Such an increase in loads is possible when a wall is designed to be as rigid as this subject wall. Soil consolidation over time and unanticipated surcharge loading from adjacent traffic could have also increased the actual lateral loads to greater than the at-rest pressure. A technical paper written by Leo Casagrande titled "Comments on Conventional Design of Retaining Structures" in the Journal of Soil Mechanics Division, February 1973, supports the notion that higher than design at-rest lateral pressures may act on a retaining wall. The technical paper reveals that these higher than design at-rest lateral pressures may develop depending on the degree of compaction of the backfill, the degree of saturation of the backfill, the type of backfill material, and the construction procedure in which the backfill was placed.

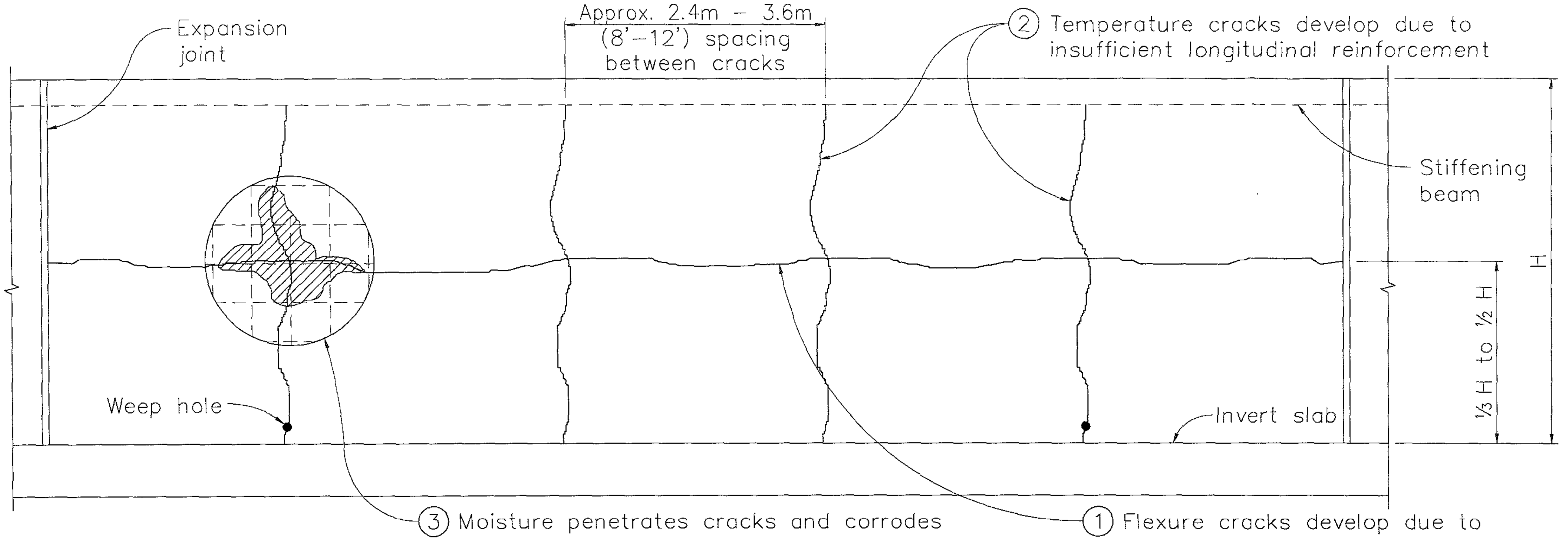
When the moments from the actual lateral loads acting on the wall were transferred to the invert slab, the location where the wall steel reinforcement was terminated simply developed more tension than the concrete alone could resist and a crack formed. Once the cracking was initiated and without tension reinforcement the crack continued to propagate through the entire thickness of the slab. The longitudinal crack observed along the invert slab started from the bottom and continued through the slab to the top. The steel reinforcement along the top of the invert slab is now acting as a dowel, preventing a sheared release along the crack. The dowel prevents slip between the two sides of the invert slab but allows rotation about the longitudinal crack. This rotational release is what causes the wall to deflect excessively.

3.1.2.3 Deficiency #3 - Trapezoidal Channel Lining Deterioration (Figure 4)

This channel lining deterioration is observed in the majority of the trapezoidal channels investigated in this Study, namely, Reach P 4 of Permanente Creek, Reaches H 2A through H 5A of Hale Creek, and Reaches PD 1 through PD 4 of the Permanente Diversion. However, it was also observed that in Reach P 23 of Permanente Creek the trapezoidal channel did not experience the same type of deterioration. The lining in Reach P 23, which was constructed in approximately 1981, was two inches thicker than its predecessors and had reinforcing bars rather than welded wire fabric. These two structural improvements alone may explain why the channel lining of Reach P 23 is performing better than those observed with channel lining deterioration.

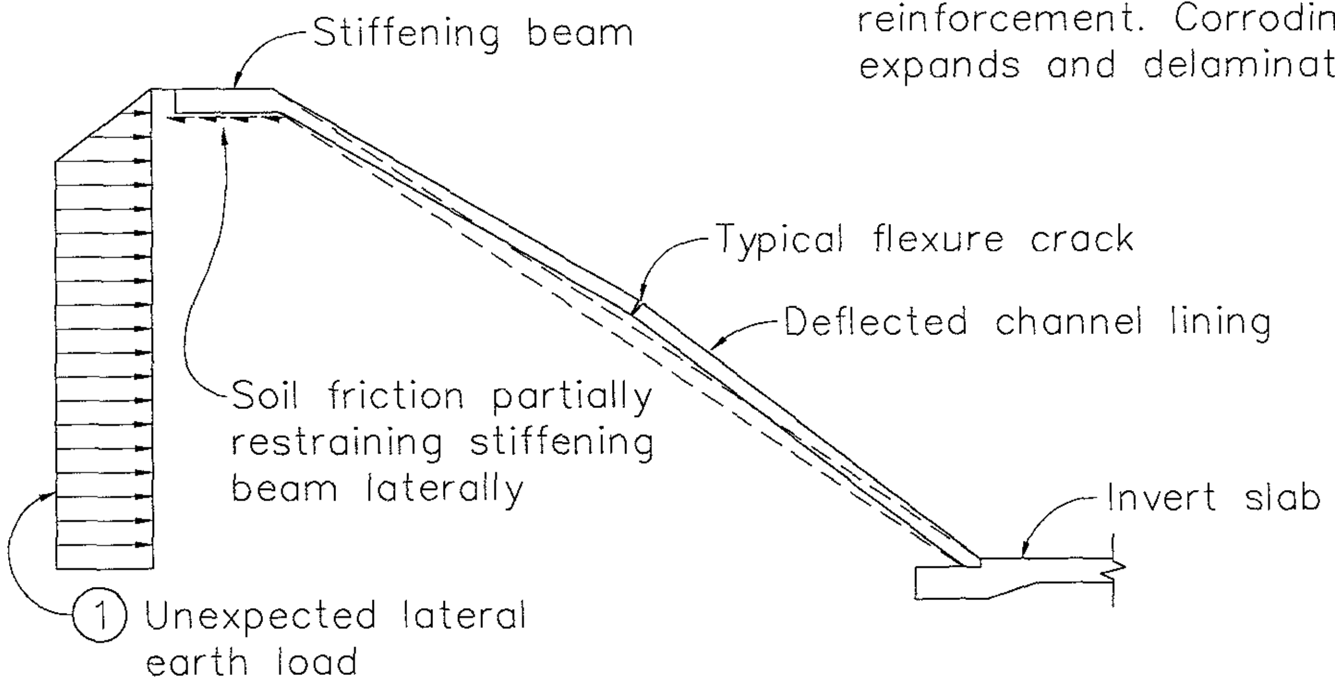
For the trapezoidal channel lining deterioration observed along the project alignment for this Study, the following sequence of events has occurred or probably will eventually occur.

1. The original design assumed the side slopes of the channel were gentle enough so that the lining would not experience any significant side wall lateral pressures. With this assumption, the thickness of the lining as well as its reinforcement was kept at a minimum.


Expansion joint
Approx. 2.4m – 3.6m (8'–12') spacing between cracks
② Temperature cracks develop due to insufficient longitudinal reinforcement
Stiffening beam
H
⅓ H to ½ H
Weep hole
Invert slab
③ Moisture penetrates cracks and corrodes reinforcement. Corroding reinforcement expands and delaminates concrete.
① Flexure cracks develop due to unexpected lateral loads on lining causing the lining to span between the stiffening beam & invert slab

ELEVATION

NTS


Stiffening beam
Typical flexure crack
Deflected channel lining
Soil friction partially restraining stiffening beam laterally
Invert slab
① Unexpected lateral earth load

PARTIAL CROSS SECTION

NTS

Note:

①, ②, ③, ... Indicates sequence of degradation activity

FIGURE 4

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PERMANENTE CREEK
FLOOD CONTROL PROJECT
STRUCTURAL INTEGRITY STUDY

DEFICIENCY #3
TRAPEZOIDAL CHANNEL
LINING DETERIORATION

DESIGNED BY DRD	DATE: 8/29/00
DRAWN BY: T. SIMMONS	SCALE: NONE
CHECKED BY: RLO	JOB No.: 99029
SHEET 30	
DRAWING No.	REV. No.
A 029–4	

99029

2. The actual side slopes of the trapezoidal channel, however, were steep enough to impart lateral loads on the channel lining. Furthermore, the as-built plans revealed that a thickened channel lip was constructed at the top of the channel lining. With the presence of the thickened channel lip, the lining tended to span from the thickened lip which was partially restrained laterally by soil friction, to the invert slab, attempting to resist the lateral earth pressure. With the channel lining not designed to resist the loads in this manner, a horizontal flexural crack formed.

3. The typical 100 millimeter (4 inch) thick lining with welded wire fabric does not have sufficient flexural capacity to resist the lateral earth pressure. The result is a horizontal flexural crack approximately located between a third to a half of the lining height from the invert slab.

4. The lack of horizontal reinforcement and the horizontal flexural crack promotes the formation of vertical temperature expansion and contraction cracks, which occur at approximately 1.22 to 2.44 meter (4 to 8 foot) centers. These vertical cracks propagate from the horizontal flexural crack.

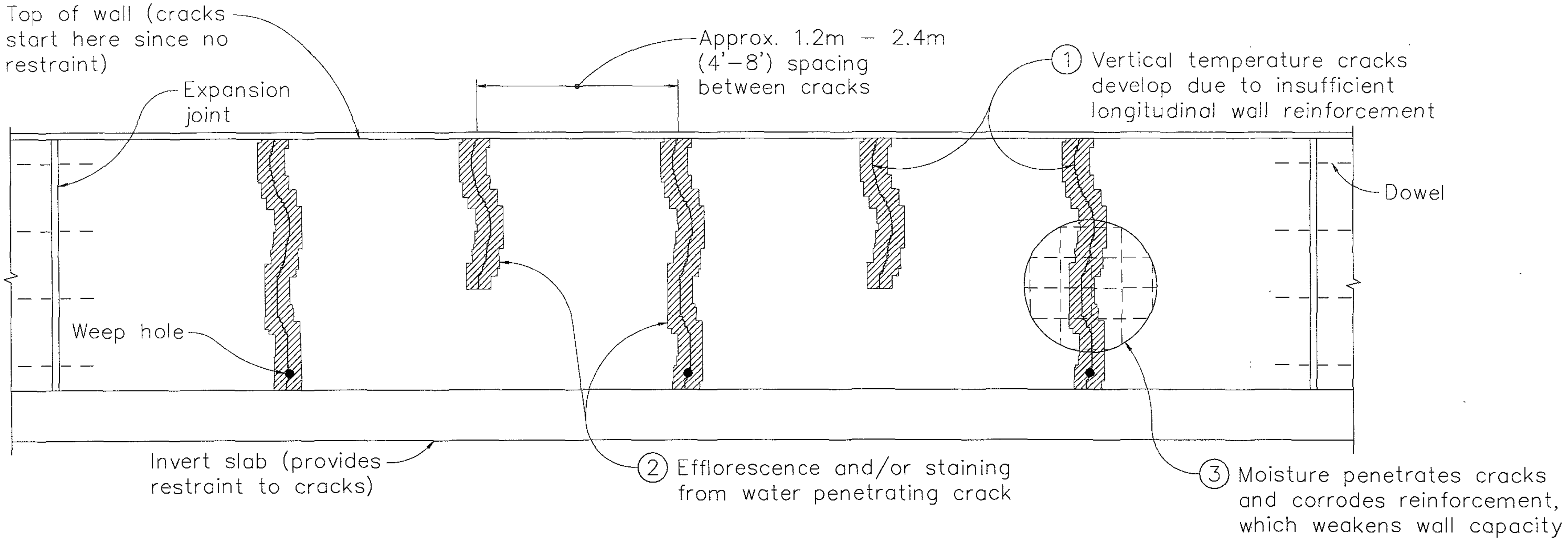
5. The horizontal and vertical cracks allow moisture to corrode the lining reinforcement. The corrosion in turn causes the reinforcement to expand and spall off the concrete cover (which is typically half the thickness of the lining).

3.1.2.4 Deficiency #4 - Vertical Temperature Expansion and Contraction Cracks in Walls (Figure 5)

Vertical temperature cracking is observed in the majority of the vertical walled sections investigated for this Study, namely Reaches P 5 through P 12 and P 15A through P 16 of Permanente Creek, Reach H 5B of Hale Creek, and Reaches PD 3 and PD 4 of the Permanente Diversion.

For the vertical temperature expansion and contraction cracks on the walls observed along the project alignment for this Study, the following sequence of events has occurred or probably will eventually occur.

1. For walls approximately 2.135 meters (7 feet) tall and greater, insufficient horizontal wall steel was provided for the given length between expansion joints.


Top of wall (cracks start here since no restraint)
Expansion joint
Approx. 1.2m – 2.4m (4'–8') spacing between cracks
① Vertical temperature cracks develop due to insufficient longitudinal wall reinforcement
Dowel
Weep hole
Invert slab (provides restraint to cracks)
② Efflorescence and/or staining from water penetrating crack
③ Moisture penetrates cracks and corrodes reinforcement, which weakens wall capacity

ELEVATION
NTS

FIGURE 5

Note:
①, ②, ③, ... Indicates sequence of degradation activity

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BCA

PERMANENTE CREEK
FLOOD CONTROL PROJECT
STRUCTURAL INTEGRITY STUDY

DEFICIENCY #4
VERTICAL TEMPERATURE CRACKS IN WALL

DESIGNED BY: DRD	DATE: 8/29/00
DRAWN BY: T. SIMMONS	SCALE: NONE
CHECKED BY: RLO	JOB No.: 99029
SHEET 32	
DRAWING No.	REV No.
A 029-5	

2. Not being influenced by the restraining effects of the invert slab and as temperature fluctuations occurred, the top of the walls experienced significant volumetric fluctuations. Because of these volumetric fluctuations caused by temperature expansion and contraction, cracks initiated at the top of walls and eventually propagated down.

3. With minimal horizontal longitudinal reinforcement in the walls, these vertical cracks were allowed to propagate downward, tending to align themselves at 1.22 to 2.44 meter (4 to 8 foot) centers commonly the spacing of the weepholes.

4. Where irrigation occurs behind the wall, runoff water seeps through the vertical cracks and causes efflorescence at the cracks indicating corrosion of the wall reinforcement.

5. The corrosion of the wall reinforcement over time spreads throughout the wall weakening and degrading the wall.

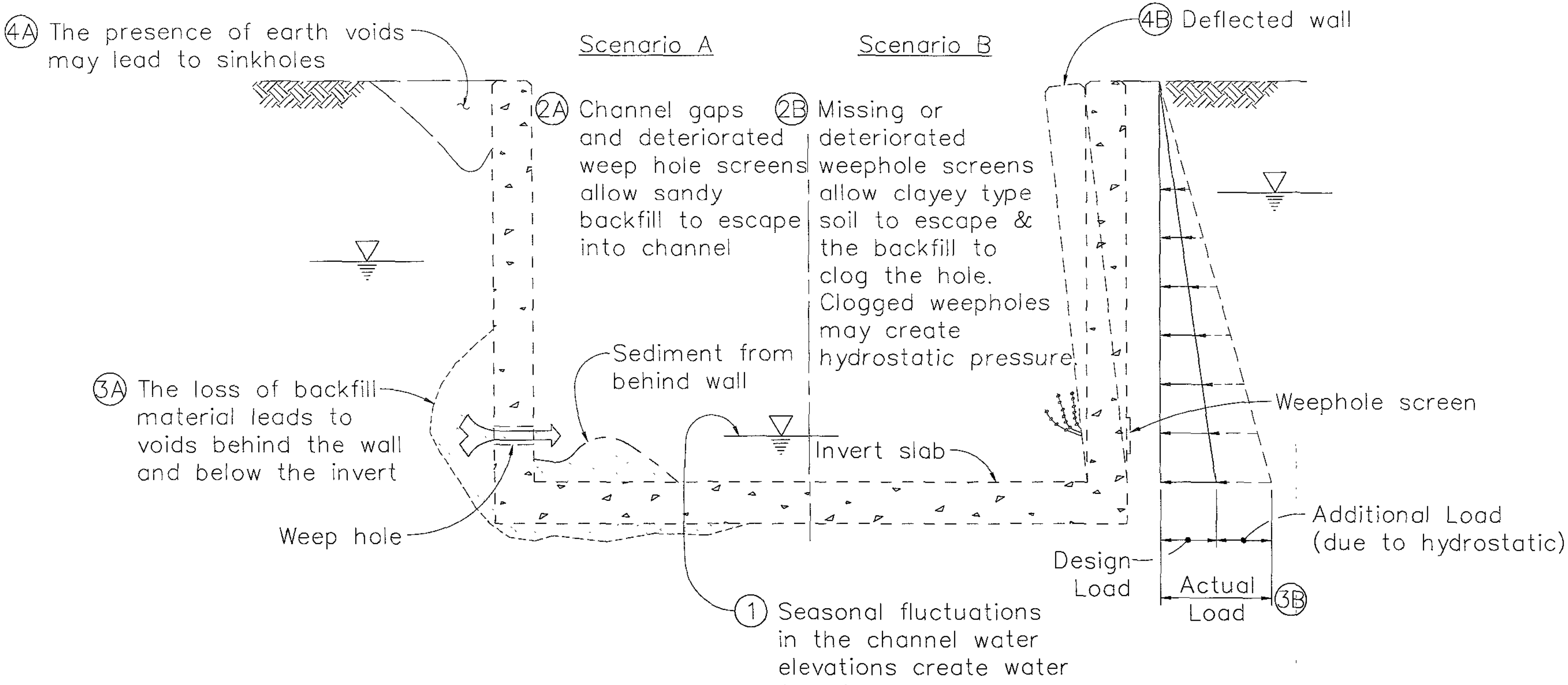
3.1.2.5 Deficiency #5 - Spillage of Backfill and Foundation Material Through Weepholes and Gaps (Figure 6)

The spillage of backfill and foundation material as previously described may occur at any location throughout the studied alignment due to the numerous weepholes and gaps observed. Currently, voids are suspected along Reaches H 2A and H 3A of Hale Creek. The clogging of the weepholes has been observed along Reaches P 5, P 6, P 7, P 8B, and P9 of Permanente Creek.

For the sediment found within the channel and voids observed behind the studied alignment, the following sequence of events has occurred or probably will eventually occur.

1. Per the as-built plans, both burlap bags and wire screens were installed on the back face of the weepholes as drainrock screens. Over time, these drainrock screens have deteriorated. Gaps at the expansion joints have been created over time due to the deterioration of the expansion joint filler. The unscreened weepholes and gaps allow for spillage of backfill and foundation material into the channel.

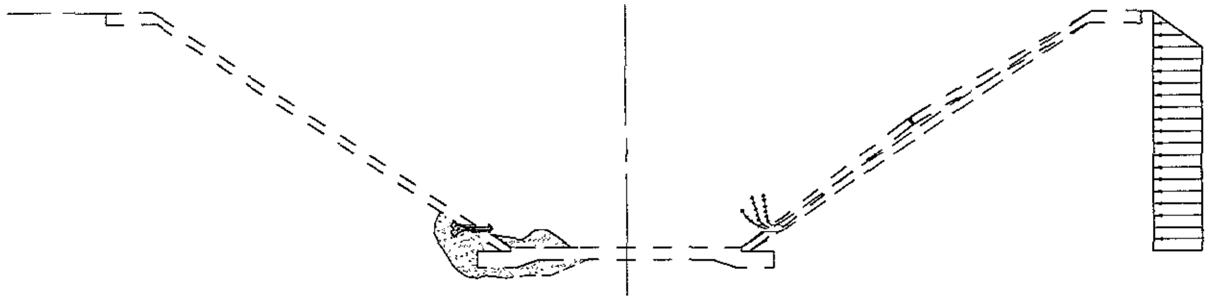
2. As the channel water rises and falls, the water flows through the weepholes and channel gaps and saturates the backfill material. As the channel water elevation drops, the water flows back out of the weepholes and channel gaps carrying with it portions of the backfill and foundation material.



④A The presence of earth voids may lead to sinkholes
Scenario A
Scenario B
④B Deflected wall
②A Channel gaps and deteriorated weep hole screens allow sandy backfill to escape into channel
②B Missing or deteriorated weephole screens allow clayey type soil to escape & the backfill to clog the hole. Clogged weepholes may create hydrostatic pressure
③A The loss of backfill material leads to voids behind the wall and below the invert
Sediment from behind wall
Weephole screen
Invert slab
Weep hole
Additional Load (due to hydrostatic)
Design Load
Actual Load
③B
① Seasonal fluctuations in the channel water elevations create water flow from the saturated backfill into the channel

SECTION

NTS



Trapezoidal sections similar

SECTION

NTS

Note:

①, ②, ③, ... Indicates sequence of degradation activity

FIGURE 6

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BCA

PERMANENTE CREEK
FLOOD CONTROL PROJECT
STRUCTURAL INTEGRITY STUDY

DEFICIENCY #5
SPILLAGE OF
BACKFILL MATERIAL

DESIGNED BY: DRD	DATE: 8/29/00
DRAWN BY: T. SIMMONS	SCALE: NONE
CHECKED BY: RLO	JOB No.: 99029
SHEET 34	

	DRAWING No.	REV. No.
A	029-6	

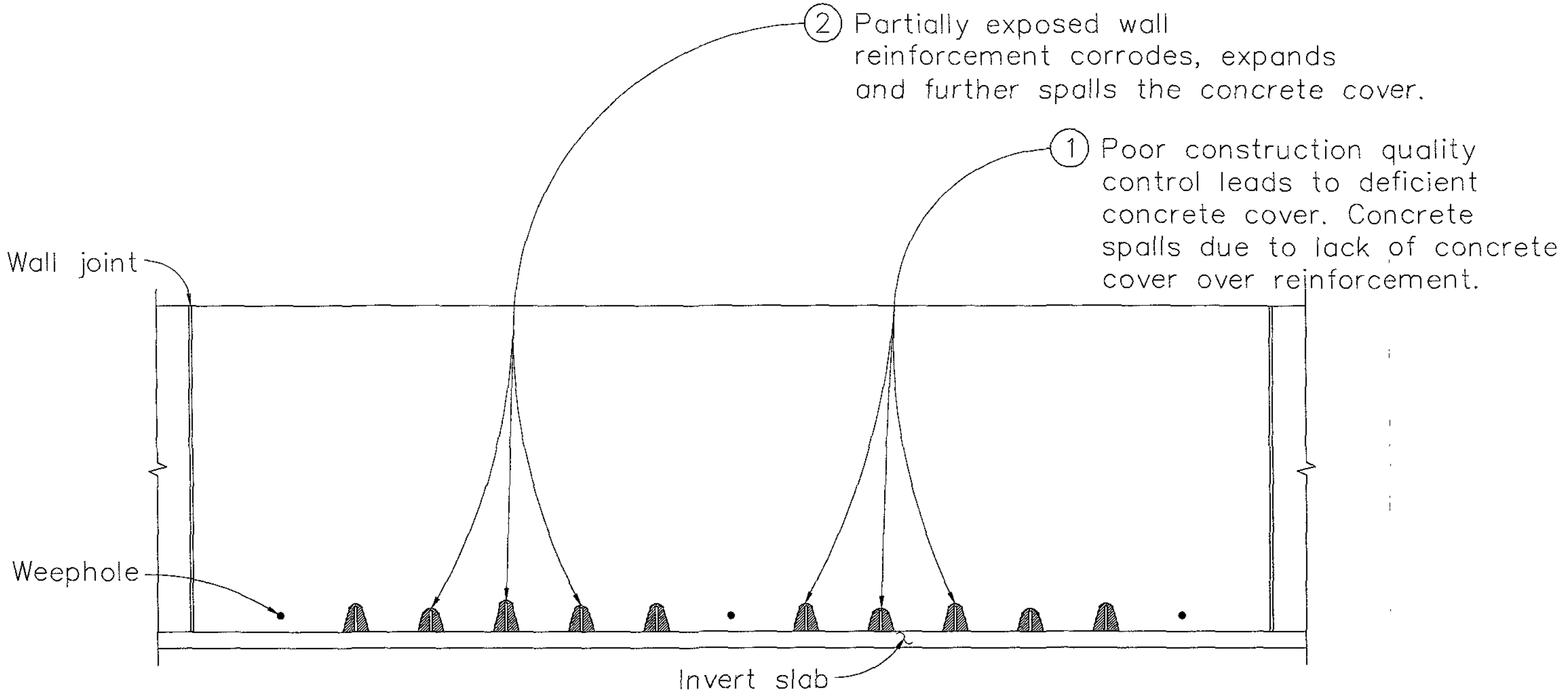
3. Over a period of time and seasonal cycles, all the crushed rock directly behind the weepholes gets removed and depending on the soil type (clay or sands) two situations would arise:
    a. In sandy backfill, the backfill material would continue to permeate through the weepholes and eventually create a void and sinkhole behind the wall or channel lining. The void may also occur beneath the invert slab causing localized loss of support and possible collapse of the invert into the void.
    b. In clayey backfill, the backfill material would partially fill the weepholes allowing vegetation growth, which eventually clogs the weepholes and allows for unaccounted additional hydrostatic wall pressure. This additional hydrostatic wall pressure may lead to Deficiency Number 1 - Excessive Wall Deflections.

3.1.2.6 Deficiency #6 - Exposed Reinforcement Due to Lack of Concrete Cover (Figure 7)

Exposed reinforcement due to lack of concrete cover can occur at any location where construction quality control was relaxed or overlooked. For the project alignment investigated for the Study, exposed reinforcement due to lack of concrete cover has been observed at Reach P 16 of Permanente Creek and at Reaches H 1B, H 2B, H 3A, H 3B, H 4, H 5A, and H 5B of Hale Creek.

For exposed reinforcement observed along the base of the walls or lining, the following sequence of events has occurred or probably will eventually occur.

1. Initial poor construction quality has resulted in insufficient concrete cover over the wall reinforcing.
2. Over a period of time, exposure to the elements deteriorates the concrete enough to cause the spalling of the concrete cover at various locations.
3. The exposed reinforcement corrodes and expands causing further concrete spalling.



② Partially exposed wall reinforcement corrodes, expands and further spalls the concrete cover.
① Poor construction quality control leads to deficient concrete cover. Concrete spalls due to lack of concrete cover over reinforcement.
Wall joint
Weephole
Invert slab

ELEVATION

NTS

FIGURE 7

Note:

①, ②, ③, ... Indicates sequence of degradation activity

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PERMANENTE CREEK
FLOOD CONTROL PROJECT
STRUCTURAL INTEGRITY STUDY

DEFICIENCY #6
EXPOSED REINFORCEMENT DUE TO LACK OF CONCRETE COVER

DESIGNED BY: DRD	DATE: 8/29/00
DRAWN BY: T. SIMMONS	SCALE: NONE
CHECKED BY: RLO	JOB No.: 99029
SHEET 36	
DRAWING No. A 029-7	REV. No.

3.1.2.7 Deficiency #7 - Wall Expansion Joint Deterioration (Figure 8)

Expansion joint deterioration may occur at any expansion joint along the project alignment. Currently, expansion joint deterioration (in varying degrees of severity) has been observed at least once at every reach investigated in the Study.

For the wall expansion joint deterioration observed along the studied alignment, the following sequence of events has occurred or probably will eventually occur.

1. Deterioration of the wall expansion joint filler due to time and weathering caused the filler to fall out and wash away creating a gap in the wall.

2. Past seismic movement of these structures may have possibly further opened these wall gaps and may have also pounding the wall edges together. The pounding of the wall edges could have caused the concrete to spall and further expose the wall dowels.

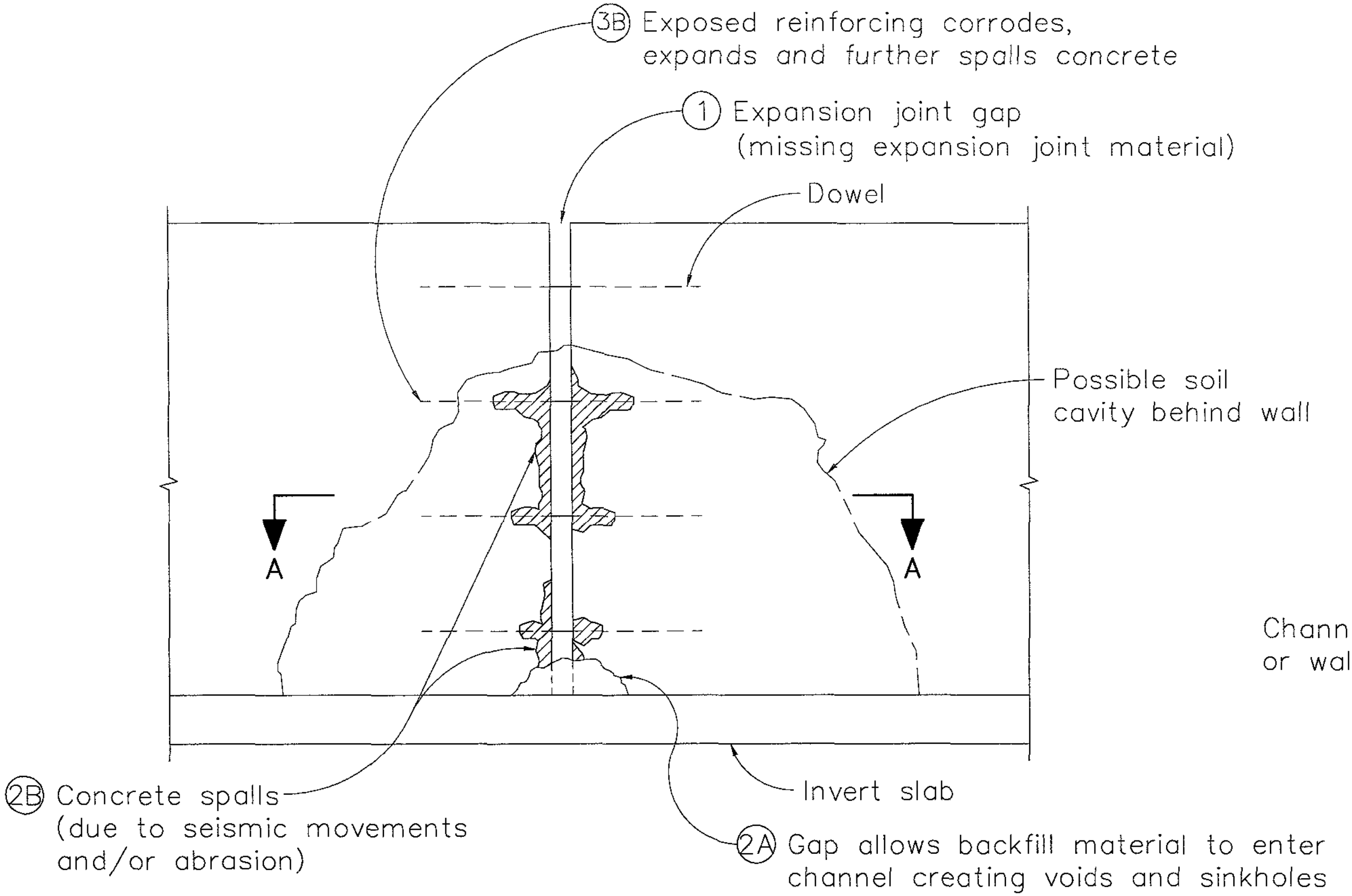
3. Debris in the channel water running over the wall gaps further abrades and spalls the concrete. The channel water also initiates the corrosion of the exposed wall dowels.

    a. The corroding wall dowels expand and cause further spalling of the concrete cover.

    b. The gaps at the wall expansion joints allow backfill material to enter the channel.

    c. Over time, the backfill material that enters the channel will create voids and/or sinkholes behind the wall.

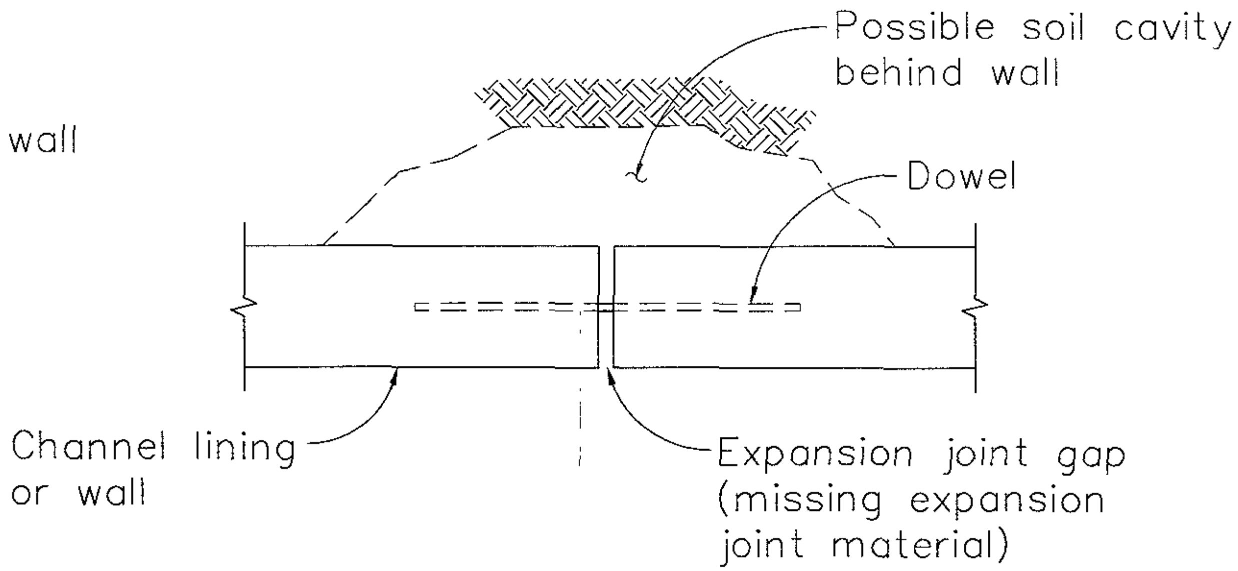
Deficiency pattern locations by reach are summarized in Table 4 (Deficiency Patterns by Reach).



3B Exposed reinforcing corrodes, expands and further spalls concrete
1 Expansion joint gap (missing expansion joint material)
Dowel
Possible soil cavity behind wall
A
A
2B Concrete spalls (due to seismic movements and/or abrasion)
Invert slab
2A Gap allows backfill material to enter channel creating voids and sinkholes

ELEVATION

NTS



Possible soil cavity behind wall
Dowel
Channel lining or wall
Expansion joint gap (missing expansion joint material)

SECTION A-A

NTS

FIGURE 8

Note:

①, ②, ③, ... Indicates sequence of degradation activity

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PERMANENTE CREEK
FLOOD CONTROL PROJECT
STRUCTURAL INTEGRITY STUDY

DEFICIENCY #7
WALL EXPANSION
JOINT DETERIORATION

DESIGNED BY: DRD	DATE: 8/29/00
DRAWN BY: T. SIMMONS	SCALE: NONE
CHECKED BY RLO	JOB No.: 99029
SHEET 38	
DRAWING No.	REV No.
A 029-8	

Table 4
Deficiency Patterns by Reach

Segment	Station	District Reach No. (See Table 1)	Deficiency
15	38+82 – 39+45	P4	Moderate Trapezoidal Channel Lining Deterioration
15A	39+53	P5	Minor Shrinkage Cracking
15A	39+53	P5	Minor Exposed Rebar
15A	39+53	P5	Minor Honeycombing and Staining
16	40+07 – 41+00	P5	Moderate Vertical Temperature Cracks
16	40+07 – 41+00	P5	Severe Wall Deflection
16	40+07 – 41+00	P5	Minor Abrasion
17	41+00 – 42+56	P5	Moderate Vertical Temperature Cracks
17	41+00 – 42+56	P5	Severe Wall Deflection
17	41+00 – 42+56	P5	Minor Abrasion
18	42+56 – 44+00	P6	Moderate Vertical Temperature Cracks
18	42+56 – 44+00	P6	Severe Wall Deflection
18	42+56 – 44+00	P6	Minor Abrasion
19	44+00 – 45+50	P6 & P7	Moderate Vertical Temperature Cracks
19	44+00 – 45+50	P6 & P7	Severe Wall Deflection
19	44+00 – 45+50	P6 & P7	Minor Abrasion and Efflorescence
20	45+50 – 47+00	P7	Moderate Vertical Temperature Cracks
20	45+50 – 47+00	P7	Severe Wall Deflection
20	45+50 – 47+00	P7	Minor Abrasion and Efflorescence
21	47+00 – 48 +50	P7 & P8A	Moderate Vertical Temperature Cracks
21	47+00 – 48 +50	P7 & P8A	Severe Wall Deflection
21	47+86	P8A	Minor Delamination
21	47+86	P8A	Severe Differential Wall Deflection
22	48+50 – 50+00	P8A & P8B	Moderate Vertical Temperature Cracks
22	48+50 – 50+00	P8A & P8B	Severe Wall Deflection
22	48+50 – 50+00	P8A & P8B	Minor Abrasion and Efflorescence
23	50+00 – 51+50	P8B & P9	Moderate Vertical Temperature Cracks
23	50+00 – 51+50	P8B & P9	Severe Wall Deflection
23	50+00 – 51+50	P8B & P9	Minor Abrasion and Efflorescence
23	51+10	P8B	Severe Differential Wall Deflection
24	51+50 – 53+00	P9	Moderate Vertical Temperature Cracks
24	51+50 – 53+00	P9	Severe Wall Deflection
24	51+50 – 53+00	P9	Minor Abrasion, Efflorescence and Pop-Outs
25	53+00 – 54+50	P9 & P10	Moderate Vertical Temperature Cracks

Table 4
Deficiency Patterns by Reach

Segment	Station	District Reach No. (See Table 1)	Deficiency
25	53+00 – 54+50	P9 & P10	Severe Wall Deflection
25	53+00 – 54+50	P9 & P10	Minor Abrasion and Efflorescence
26	54+50 – 56+00	P10 & P11A	Moderate Vertical Temperature Cracks
26	54+50 – 56+00	P10 & P11A	Severe Wall Deflection
26	54+50 – 56+00	P10 & P11A	Minor Abrasion and Efflorescence
27	56+00 – 57+50	P11A & P11B	Moderate Vertical Temperature Cracks
27	56+00 – 57+50	P11A & P11B	Severe Wall Deflection
27	56+00 – 57+50	P11A & P11B	Minor Abrasion and Efflorescence
27	56+27	P11A	Moderate Joint Separation/Crack
27	56+27	P11A	Exposed Rebar Moderate
27	56+56	P11A	Moderate Shear Crack
27	57+15	P11A	Moderate Joint Crack
28	57+50 – 59+00	P11B & P12	Moderate Vertical Temperature Cracks
28	57+50 – 59+00	P11B & P12	Severe Wall Deflection
28	57+60	P11B	Moderate Unknown Crack
28	57+60	P11B	Moderate Shear Crack
28	57+75	P11B	Moderate Shear Crack
28	58+45	P11B	Moderate Shear Crack
29	59+00 – 59+70	P12	Moderate Vertical Temperature Cracks
29	59+00 – 59+70	P12	Severe Wall Deflection
29	59+20	P12	Moderate Shear Crack
30	59+70 – 60+29	P12	Moderate Vertical Temperature Cracks
30	59+70 – 60+29	P12	Severe Wall Deflection
30	60+29 – 61+00	P13A	Minor Efflorescence
31	61+06	P13A	Moderate Unknown Crack
31	61+06	P13A	Moderate Exposed Rebar
31	61+40 – 61+69	P13A	Moderate Abrasion
31	62+12	P13A	Minor Efflorescence
31	62+26	P13A	Moderate Unknown Crack
31	62+26	P13A	Moderate Exposed Rebar
33	65+04	P14	Minor Efflorescence and Staining
33	65+50	P14	Moderate Efflorescence and Staining
34	65+50 – 67+00	P14	Minor Efflorescence at Joints of Segment
34	65+81	P14	Minor Abrasion

Table 4
Deficiency Patterns by Reach

Segment	Station	District Reach No. (See Table 1)	Deficiency
34	65+81	P14	Moderate Exposed Rebar
34	66+79	P14	Minor Abrasion
34	66+79	P14	Moderate Exposed Rebar
34	66+79	P14	Severe Exposed Rebar (top slab)
35	67+55	P14	Minor Unknown Crack
35	67+55	P14	Minor Efflorescence
36	68+50 – 70+00	P14	Minor Efflorescence at Joints of Segment
37	70+31 – 70+55	P14	Severe Abrasion
37	70+31 – 70+55	P14	Moderate Exposed Rebar
38	70+85	P14	Moderate Unknown Crack
38	70+80 – 72+00	P14 & P15A	Moderate Efflorescence at Joints of Segment
38	71+49 – 72+00	P15A	Moderate Vertical Temperature Cracks
38	71+49 – 72+00	P15A	Severe Wall Deflection
39	72+00 – 73+50	P15B	Moderate Vertical Temperature Cracks
39	72+41 – 72+94	P15A & P15B	Severe Wall Deflection
40	73+50 – 75+00	P15B	Moderate Vertical Temperature Cracks
40	73+50 – 75+00	P15B	Severe Wall Deflection

Table 4
Deficiency Patterns by Reach

Segment	Station	District Reach No. (See Table 1)	Deficiency
41	75+00 – 76+50	P15B & P16	Moderate Vertical Temperature Cracks
41	75+00 – 76+50	P15B & P16	Severe Wall Deflection
41	75+62	P16	Moderate Pop-Outs
41	75+62	P16	Moderate Exposed Rebar
41	75+75	P16	Minor Abrasion
41	75+86	P16	Moderate Cavitation
41	76+38	P16	Minor Pattern Cracking
42	76+50 – 73+00	P16	Moderate Vertical Temperature Cracks
42	76+50 – 78+00	P16	Severe Wall Deflection
42	77+13	P16	Minor Pop-Out
42	77+13	P16	Minor Exposed Rebar
42	77+66	P16	Minor Exposed Rebar
42	77+73	P16	Moderate Abrasion
43	78+00 – 79+10	P16	Moderate Vertical Temperature Cracks
43	78+00 – 79+10	P16	Severe Wall Deflection
43	78+72	P16	Moderate Pop-Outs
43	79+16	P16	Moderate Pop-Outs and Spalling

Table 4
Deficiency Patterns by Reach

Segment	Station	District Reach No. (See Table 1)	Deficiency
44	01+13	H1B	Severe Abrasion and Spalling (at joint)
44	01+31	H1B	Minor Joint Crack
45	01+50 – 03+00	H1B	Moderate Separation/Crack (between slab and wall)
45	01+52	H1B	Moderate Abrasion and Delamination
45	01+52	H1B	Moderate Exposed Rebar
45	01+75	H1B	Moderate Pop-Outs and Spalling
45	02+06	H1B	Moderate Pop-Outs
45	02+08	H1B	Moderate Exposed Rebar
45	02+36	H1B	Moderate Pop-Outs
45	02+36	H1B	Moderate Exposed Rebar
45	02+56	H1B	Severe Spalling
45	02+56	H1B	Severe Exposed Rebar
45	02+80	H1B	Minor Exposed Rebar
46	03+59	H1B	Moderate Shrinkage Cracking
46	03+59	H1B	Moderate Disintegration and Spalling
46	03+59	H1B	Minor Exposed Rebar
46	04+12	H2A	Moderate Disintegration (Possible Void Below Invert)

Table 4
Deficiency Patterns by Reach

Segment	Station	District Reach No. (See Table 1)	Deficiency
46	04+28	H2A	Moderate Spalling
46	04+28	H2A	Minor Exposed Rebar
46	04+40	H2A	Minor Delamination
47	04+50 – 06+00	H2A & H2B	Moderate Trapezoidal Channel Lining Deterioration
47	04+63	H2A	Severe Disintegration and Spalling
47	04+63	H2A	Moderate Exposed Rebar
47	04+93 – 05+19	H2A	Minor Shrinkage Cracking
47	04+93	H2A	Minor Spalling
47	05+37	H2B	Moderate Shear Crack
47	05+64	H2B	Moderate Shrinkage Crack
48	06+00 – 07+50	H2B & H3A	Moderate Trapezoidal Channel Lining Deterioration
48	07+14	H2B	Moderate Pop-Outs
48	07+14	H2B	Moderate Exposed Rebar
49	07+50 – 09+00	H3A	Moderate Trapezoidal Channel Lining Deterioration
49	08+84	H3A	Moderate Spalling
49	08+98	H3A	Moderate Spalling
49	08+98	H3A	Moderate Exposed Rebar

Table 4
Deficiency Patterns by Reach

Segment	Station	District Reach No. (See Table 1)	Deficiency
50	09+00 – 10+50	H3A & H3B	Moderate Trapezoidal Channel Lining Deterioration
50	09+02	H3A	Moderate Spalling
50	09+02	H3A	Moderate Exposed Rebar
50	09+84	H3B	Moderate Disintegration and Spalling
50	10+30	H3B	Moderate Delamination
51	10+50 – 12+00	H3B & H4	Moderate Trapezoidal Channel Lining Deterioration
51	10+53	H3B	Moderate Pop-Outs
51	10+53	H3B	Moderate Exposed Rebar
51	11+42	H4	Moderate Pop-Outs
51	11+42	H4	Moderate Exposed Rebar
52	12+00 – 13+50	H4	Moderate Trapezoidal Channel Lining Deterioration
52	12+01	H4	Moderate Shear Crack
52	12+63	H4	Moderate Spalling
52	13+12	H4	Moderate Abrasion
53	13+50 – 15+00	H4 & H5A	Moderate Trapezoidal Channel Lining Deterioration
53	13+55	H4	Moderate Spalling
53	13+75	H4	Moderate Separation Crack

Table 4
Deficiency Patterns by Reach

Segment	Station	District Reach No. (See Table 1)	Deficiency
53	14+46	H5A	Severe Disintegration w/ Moderate Pop out (Possible Separation Crack)
53	14+46	H5A	Severe Exposed Rebar
53	14+56	H5A	Severe Disintegration
53	14+56	H5A	Severe Exposed Rebar
53	14+75	H5A	Moderate Pop-Outs and Spalling
53	14+75	H5A	Moderate Exposed Rebar
53	14+84	H5A	Moderate Scaling
53	14+84	H5A	Moderate Exposed Rebar
54	15+24 – 17+00	H5B	Severe Wall Deflection
54	15+24 – 17+39	H5B	Moderate Vertical Temperature Cracks
54	15+37	H5B	Minor Shrinkage Cracking
54	15+37 – 15+46	H5B	Moderate Pop-Outs
54	15+37 – 15+46	H5B	Moderate Exposed Rebar
54	15+51 – 16+56	H5B	Severe Longitudinal Failure Crack in Invert
54	15+62	H5B	Moderate Spalling
54	15+82 – 16+08	H5B	Moderate Pop-Outs

Table 4
Deficiency Patterns by Reach

Segment	Station	District Reach No. (See Table 1)	Deficiency
54	15+82 – 16+08	H5B	Moderate Exposed Rebar
54	15+90 – 16+50	H5B	Severe Wall Deflection
54	16+17 – 16+39	H5B	Moderate Pop-Outs
54	16+17 – 16+39	H5B	Moderate Exposed Rebar
54	16+41 – 16+50	H5B	Moderate Pop-Outs
54	16+41 – 16+50	H5B	Moderate Exposed Rebar
55	16+50 – 16+65	H5B	Minor Pop-Outs
55	16+50 – 16+80	H5B	Minor Exposed Rebar
55	16+50 – 17+00	H5B	Severe Wall Deflection
55	16+82	H5B	Moderate Spalling
55	17+08 – 17+39	H5B	Moderate Pop-Outs
55	17+08 – 17+39	H5B	Moderate Exposed Rebar
56	90+40 – 90+60	P20	Minor Staining
57	00+22	PD1	Minor Unknown Crack
58	00+75 – 02+00	PD1	Moderate Trapezoidal Channel Lining Deterioration
58	00+84	PD1	Minor Disintegration & Spalling
58	01+02 – 01+11	PD1	Moderate Trapezoidal Channel Lining Deterioration
58	01+12	PD1	Vegetation Growing Out of Joint
58	01+29 – 01+37	PD1	Moderate Trapezoidal Channel Lining Deterioration
58	01+39 – 02+00	PD1	Minor Trapezoidal Channel Lining Deterioration
58	01+48	PD1	Minor Spalling
59	02+00 – 3+50	PD1 – PD2	Moderate Trapezoidal Channel Lining Deterioration
59	02+06	PD1	Minor Unknown Crack But Probably a Weakened Plane
59	02+76	PD2	Minor Unknown Crack
60	03+50 – 05+00	PD2	Moderate Trapezoidal Channel Lining Deterioration
60	03+50 – 05+00	PD2	Approx. 6" of Sediment Over the Invert
60	03+68	PD2	Moderate Spalling
60	03+79	PD2	Moderate Trapezoidal Channel Lining Deterioration
60	04+29	PD2	Moderate Spalling
60	04+59	PD2	Moderate Spalling
61	05+00 – 06+50	PD2	Moderate Trapezoidal Channel Lining Deterioration
61	05+00 – 06+50	PD2	Approx. 6" of Sediment Over the Invert
61	05+07	PD2	Moderate Spalling

Table 4
Deficiency Patterns by Reach

Segment	Station	District Reach No. (See Table 1)	Deficiency
61	05+30	PD2	Moderate Spalling
61	05+55	PD2	Scupper Installed on Channel Wall (Rough Saw Cut)
62	06+50 – 08+00	PD2	Moderate Trapezoidal Channel Lining Deterioration
62	06+50 – 08+00	PD2	Approx. 6" of Sediment Over the Invert
62	07+27	PD2	Scupper Installed on Channel Wall (Rough Saw Cut)
63	08+00 – 09+50	PD2	Approx. 6" of Sediment Over the Invert
63	08+00 – 09+50	PD2	Moderate Trapezoidal Channel Lining Deterioration
63	09+00	PD2	Moderate Spalling
64	09+50 – 11+00	PD2	Moderate Trapezoidal Channel Lining Deterioration
64	09+50 – 11+00	PD2	Approx. 6" of Sediment Over the Invert
64	09+73	PD2	Minor Spalling
64	09+95	PD2	Moderate Spalling
64	10+28	PD2	Minor Pattern Cracking
64	10+56	PD2	Moderate Separation Crack (at Joint)
64	10+56	PD2	Moderate Exposed Rebar
64	10+90	PD2	Moderate Spalling

Table 4
Deficiency Patterns by Reach

Segment	Station	District Reach No. (See Table 1)	Deficiency
65	11+00 – 12+50	PD2	Moderate Trapezoidal Channel Lining Deterioration
65	11+32	PD2	Moderate Shrinkage Crack
65	11+49	PD2	Moderate Abrasion and Warping
65	11+49	PD2	Minor Exposed Rebar
65	12+34	PD2	Moderate Spalling
66	12+50 – 14+00	PD2	Moderate Trapezoidal Channel Lining Deterioration
66	12+56	PD2	Moderate Spalling
67	14+00 – 15+50	PD3	Moderate Trapezoidal Channel Lining Deterioration
67	14+39	PD3	Minor Spalling
67	14+73	PD3	Moderate Spalling
67	14+73	PD3	Moderate Exposed Rebar
67	15+39	PD3	Moderate Spalling
67	15+39	PD3	Moderate Exposed Rebar
68	15+50 – 16+00	PD3	Moderate Trapezoidal Channel Lining Deterioration
68	16+60 – 17+00	PD3	Moderate Pop-Outs
68	16+00 – 17+00	PD3	Moderate Vertical Temperature Cracks
68	16+60 – 17+00	PD3	Moderate Wall Deflection

Table 4
Deficiency Patterns by Reach

Segment	Station	District Reach No. (See Table 1)	Deficiency
69	17+00 – 18+82	PD3 & PD4	Moderate Wall Deflection
69	17+00 – 19+00	PD3 & PD4	Moderate Pop-Outs
69	17+00 – 19+00	PD3 & PD4	Moderate Efflorescence
69	17+00 – 19+00	PD3 & PD4	Moderate Vertical Temperature Cracks
69	18+82	PD4	Severe Abrasion
69	18+82	PD4	Severe Exposed Rebar
69	18+90	PD4	Severe Differential Wall Deflection
70	19+00 – 20+50	PD4	Moderate Trapezoidal Channel Lining Deterioration
70	19+94	PD4	Moderate Spalling
71	20+50 – 21+70	PD4	Moderate Trapezoidal Channel Lining Deterioration
71	20+53	PD4	Moderate Spalling
71	20+81	PD4	Moderate Spalling
71	21+52	PD4	Moderate Joint Separation/Crack
71	21+64	PD4	Severe Shear Crack
72	106+30	P23	Severe Spalling
72	106+30	P23	Severe Exposed Rebar
73	107+00 – 108+10	P23	Minor Abrasion
73	108+73	P23	Moderate Shear Crack
73	108+75	P23	Moderate Pop-Outs
73	108+75	P23	Moderate Exposed Rebar

3.2 Summary Maps

The following Summary Maps were prepared to show where different types of deterioration were observed along the studied alignment: 1) Concrete Cracking, 2) Surface Defect, 3) Exposed Reinforcement, 4) Structural Deformation, and 5) Test Result, and 6) Deficiency Pattern. These maps are described below and included in Appendix B (*Summary Maps*) in the order that follows.

3.2.1 Concrete Cracking Summary Map

This map shows the density of cracking for the various channel types along the studied alignment and aided in the formulation of the structural deficiencies.

A Concrete Cracking Summary Map was developed to display the location and identify the severity of all the cracks that were encountered during the field inspection of the channels. These cracks, which were documented in the site inspection forms, ranged in severity from minor to severe. Any crack that was encountered along the studied alignment was recorded, classified and assigned an appraisal rating per the Site Inspection Procedure Guide (Supplement 3).

3.2.2 Surface Defect Summary Map

This map shows the density of surface defects for the various channel types along the studied alignment and aided in the formulation of the structural deficiencies.

A Surface Defect Summary Map was developed to display the location and identify the severity of all the surface defects that were encountered during the field inspection of the channels. These surface defects, which were documented in the site inspection forms, ranged in severity from minor to severe. Any surface defect that was encountered along the studied alignment was recorded, classified and assigned an appraisal rating per the Site Inspection Procedure Guide (Supplement 3).

3.2.3 Exposed Reinforcement Summary Map

This map shows the density of exposed reinforcement for the various channel types along the studied alignment and aided in the formulation of the structural deficiencies.

An Exposed Reinforcement Summary Map was developed to display the location and identify the severity of all the exposed reinforcement that was encountered during the field inspection of the channels. The locations of exposed reinforcement, which were documented in the site inspection forms, ranged in severity from minor to severe. Any exposed reinforcement encountered along the studied alignment was recorded, classified and assigned an appraisal rating per the Site Inspection Procedure Guide (Supplement 3).

3.2.4 Structural Deformation Summary Map

This map shows the locations where deflections for the various channel types along the studied alignment occur and aided in the formulation of the structural deficiencies.

A Structural Deformation Summary Map was developed to display the location and identify the severity of all the measurable deflections that were encountered during the field inspection of the channels. These deflections, which were documented in the site inspection forms, ranged in severity from minor to severe. Any structural deformation encountered along the studied alignment was recorded, classified and assigned an appraisal rating per the Site Inspection Procedure Guide (Supplement 3).

3.2.5 Test Result Summary Map

This map shows the materials test locations.

A Test Result Summary Map was developed to display the locations of concrete corings, borings, and Half Cell Potential tests locations completed during the Materials Testing Program along the studied alignment.

3.2.6 Deficiency Pattern Summary Map

This map shows the locations where the seven deficiencies occur along the studied alignment.

Once all the pertinent information from the site inspection forms was transferred to the respective summary maps (i.e., Concrete Cracking, Surface Defect, Exposed Reinforcement, and Structural Deformation), deficiency patterns became apparent. Seven deficiency patterns that affect the structural integrity or functionality of the channels were identified. These seven deficiencies were placed on one map to visually summarize and focus on the deteriorating segments of the project alignment. This information is also summarized in Table 4 (*Deficiency Pattern Summary*) on page 39. An explanation of how and why each of those deficiencies occurred is presented on the map.

3.3 Materials Testing Findings

This section presents the findings of the Materials Testing portion of the Study, including the Subsurface Investigation as described below.

3.3.1 Materials Tests

The concrete channel facilities within the project limits of Permanente Creek, Hale Creek and Permanente Diversion consist of vertical walled channels or trapezoidal channel linings and box culverts. Based on the borings, soil samples obtained from the weepholes and the cores, and review of the as-built boring logs, it appears the channel walls were not backfilled with granular backfill during their construction. Based on the clayey soils encountered in borings drilled behind the walls, and the clogged condition of the weepholes observed during field visits, the channel walls were likely subjected to higher loads than those for which they were originally designed. This is also indicated by the crack pattern and excessive wall deflections. For purposes of analysis, the lateral earth pressures presented in Supplement 6 (*Materials Testing Reports*) may be used. A triangular earth pressure distribution is the recommended distribution for analyzing the vertical walls and was used in the analysis of this study. These walls should be designed for active earth pressure if the top of the walls will deflect at least 0.01 H (where H is the height of the wall). Due to the stiffness of the walls, if the deflections at the top of the walls are smaller than those required to mobilize active earth pressure, then the walls should be designed for at-rest earth pressures. These recommendations were used in the analysis of this study.

The typical pattern of cracking for trapezoidal linings consists of vertical temperature cracks and horizontal flexural cracks located at approximately mid-height to one-third height from the channel invert. The trapezoidal lining walls also appear to be restrained at the top with a thickened edge. Based on the observed crack pattern and the clayey soil, a rectangular or trapezoidal earth pressure distribution is recommended for checking the structural adequacy of the trapezoidal channel and was used in the analysis of this study.

Corrosion tests were performed on soil samples collected from the site. The corrosion test results are shown on the Test Result Summary Map in Appendix B. No groundwater was encountered during the field investigation. The soil resistivities (1300 to 2700 ohm-cm), pH (7.1 to 8.0), sulfate content (21.6 to 66.2 parts per million [PPM]) and chloride content (3.0 PPM to 9.3 PPM) for the soils varied throughout the alignment, but not to a significant degree. Based on these test results, the on-site soils may be classified to have negligible corrosion potential.

The Materials Testing Program also consisted of a Subsurface Investigation and Laboratory Testing as described below.

3.3.2 Subsurface Conditions

Based on the field exploration performed for this project and study of the site geology and boring logs prepared for previous studies, the soils underlying the site consist of alluvial soils, mainly alternating layers of clays, sands and gravel. Channel wall backfill was not encountered in the borings. Based on review of the as-built information, it appears that granular backfill was not used during the construction of the concrete channel facilities.

The layers of clays, sands and gravel encountered in the borings drilled for this project were typically about 1.5 to 2 meters (5.0 to 6.6 feet) thick. The soils in the upper 2 meters (6.6 feet) at the site are predominantly clays. The clays encountered in the borings have low to high plasticities and are classified as LEAN or FAT CLAYS on the boring logs. The clays are generally stiff to hard in consistency. Sand layers, interbedded with the clay and gravel layers, underlie the site. The sands encountered in the borings are fine to medium grained and usually contain substantial amounts of clayey or silty fines.

Based on the field sampler penetration blow counts and laboratory test results, the sands are loose to dense. Scattered gravel layers were also encountered in the borings drilled for the project. Most of the gravel layers at the site appear to be located at depths of 5 to 6 meters (16.4 to 19.7 feet) below the existing grade. The gravel layers contain silty and clayey fines and are usually dense.

Groundwater was not encountered in soil borings drilled during the investigation or in previous investigations. It should be noted that the groundwater level at the site may change with passage of time due to groundwater fluctuations from season to season, weather conditions, flows in the creeks, and other factors which may not have been present at the time of the investigation.

Detailed descriptions of the material encountered in the exploratory borings are presented on the boring logs in Supplement 6 (*Materials Testing Reports*). The descriptions and related information presented on these logs depict subsurface conditions at the locations indicated on the

Site Plans and on the particular date noted on the logs. Subsurface conditions at other locations may differ from the conditions occurring at the locations explored. In addition, passage of time may result in a change in the soil conditions at these locations due to environmental changes.

3.4 As-Built Analysis and Methodology for Estimating Remaining Channel Life

Data gathered in the field was used in conjunction with knowledge of as-built plans and soil conditions to develop a method for estimating the remaining life of each of the different types of channel structures as described below. To help explain the reoccurring structural deficiencies recorded in the field, an analysis of the as-built plans was performed. Two types of analyses were specifically conducted: 1) a structural demand versus capacity analysis, and 2) a thorough examination of the structural details.

One purpose of the As-Built Analysis was to determine whether these facilities were designed to the applicable code of the time they were built. Although it is commonly known in the industry that concrete will gain strength with time, designers are not allowed to use the higher concrete strength values attained after several years. Therefore, the analysis needed to determine if the design was deficient given the specified allowable concrete strength. The specified allowable design concrete strength is the target concrete strength at 28 days and determines how much cement, aggregate and water is required in the concrete mix design during construction. The design concrete strength is typically specified on the plans for the contractor.

Another goal of the As-Built Analysis was to actually determine what caused the cracks and deficiencies identified. In this analysis, the higher concrete strengths found through the Materials Testing Program were used to calculate if the "flexural wall failure" or other deficiency would theoretically occur. The results of these calculations would verify the premise of each deficiency.

The results from these tests provided the engineer with more insight for the evaluation of the structural life expectancy of each reach. Using the as-built data, as-built analyses were performed on each channel section that exhibited a specific deficiency pattern. The results of the analyses determined whether the original designs were performed to the governing code. The results also contributed to the correlation to the deficiency patterns. Segments that did not exhibit the same deficiency patterns were also analyzed and used as verification of the deficiency hypotheses.

3.4.1 Remaining Life Methodology

A structural demand versus capacity analysis consists of calculating the various structural capacities of the as-built structure (incorporating the details found in the as-built plans) and comparing those capacities to their respective demands or code requirements. The analysis checks to see if the as-built structure is capable of resisting the actual structural demands being experienced. It also verifies whether the assumptions made during the original design are valid.

An examination of the as-built structural details consists of investigating the minor nuances that separate a poorly detailed structure from a well-detailed one. Contributing factors may include the geometry and layout of the reinforcement, the location of the wall construction joint, the drainage details, the details of the expansion joints, and the overall geometry of the channel sections.

In conjunction with the results of the Material Testing Program, the As-Built Analysis provided enough information to estimate the structural life expectancy of each reach. Although the half-cell potential tests provided more qualitative than quantitative results, they provided the engineer with insight on how corrosion may be affecting the structure. From this, engineering judgement could be established to determine the estimated structural life expectancies of the reach. The structural life expectancies were based on the actual wall deflections rather than on the severity of corrosion of the reinforcing steel. This is because corrosion of the reinforcing bars contributes to the vertical walled channel deflection. Therefore, corrosion is already accounted for when basing the structural life expectancies on the wall deflection.

The severity of concrete cracking and corrosion were used to help determine the life expectancies for the concrete lined trapezoidal channels and box culverts. For the vertical walled channels, the wall deflections observed were compared to the yield deflection calculated during the As-Built Analysis. Properly designed and detailed walls will not reach their yield deflection prior to attaining the lateral soil pressure distribution that was assumed in the original design. This is because once a wall reaches its yield deflection, its resistance to additional deflection is significantly reduced. Therefore, the greater the observed wall deflection is over the yield deflection, the more likely the wall will continue to deflect until it collapses. The structural life expectancies for the vertical walled channels were assigned as follows:

If $0.75\Delta_y \leq \Delta_{wall} < \Delta_y$, then 15-20 years expected.
If $\Delta_y \leq \Delta_{wall} < 3\Delta_y$, then 10-15 years expected.
If $3\Delta_y \leq \Delta_{wall} < 6\Delta_y$, then 5-10 years expected.
If $6\Delta_y \leq \Delta_{wall}$, then 0-5 years expected.*

Where Δ_y is the yield deflection of the wall and Δ_{wall} is the top of wall deflection observed.

The yield deflection of the wall, Δ_y, can be calculated by the following equation:

$$\Delta_y = 0.75 \times 10^{-4} \times h^2 \text{ (inches)}$$

Where h is the height of the wall in inches (from the top of invert to the top of wall).

*Note: If the top of wall deflection, Δ_{wall}, is greater than or equal to $0.175 \times h$, then a temporary or permanent repair of the deflected vertical walled channel is recommended as a high priority.

3.4.2 Remaining Life Estimates

The structural life expectancies for the vertical walled channels were based on engineering judgement, which takes into consideration the amount of stress and corrosion in the main reinforcing steel. Unfortunately, there are no definitive guidelines that determine when a structure is expected to collapse.

For the concrete lined trapezoidal channels, the extent of concrete cracking and corrosion of the reinforcement within the lining (also known as trapezoidal channel lining deterioration) determined the remaining structural life expectancies. Since the thickness of the lining and the reinforcement was kept at a minimum and the date in which these channels were constructed is nearly the same (circa 1960), trapezoidal channel linings that were observed with this deterioration were assigned a reduced, remaining structural life expectancy of 5-10 years. The structural life expectancy of 5-10 years for the trapezoidal channel lining is based on engineering judgement. That engineering judgement takes into consideration the extent of concrete cracking along the lining and the amount of corrosion within the reinforcing steel. Unfortunately, there are no definitive guidelines that determine when a concrete lining is expected to completely fail.

Segments that did not exhibit signs of channel deterioration and corrosion were assumed to last up to their original life expectancy of 50 to 60 years from construction. Therefore, their structural life expectancy would be calculated as the difference between its original life expectancy of 50 to 60 years and the age of the structure.

4.0 CONCLUSIONS AND RECOMMENDATIONS

This section describes the conclusions drawn from the findings of the Study, including the general condition of the facilities, applicable repair or replacement options for each of the deficiencies based on their life expectancies, and associated cost estimates. It also summarizes professional recommendations including which sections should be repaired or replaced, what maintenance and monitoring programs should be implemented, and what should be considered for future design and construction.

The following tables included in this section summarize the recommendations:

- *Table 5 (Channel Inspection and Maintenance Guidelines)* describes the general guidelines and recommendations for channel inspection and maintenance.
- *Table 6 (Repair Alternative Cost Summary)* breaks down the amount of channel segment that is recommended to be repaired in 0 to 5 years, 5 to 10 years, and 10 to 15 years and summarizes the associated costs and added life expectancy of each repair option.
- *Table 7 (Channel Repair Prioritization and Cost Estimates)* indicates per reach the remaining life expectancy, types of deficiency patterns, the percentage of reach the deficiency affects, recommended repair alternatives, additional life each repair alternative adds, and associated cost for each repair alternative. This table provides pertinent information to allow the District to prioritize their options.

The section is organized as follows:

Conclusions and Basis for Recommendations
Summarizes the general channel conditions and describes the basis for developing recommendations for repair or replacement.

General Concrete Channel Design Recommendations
Describes the channels design recommendations for each of the seven types of deficiencies identified.

Channel Inspection and Maintenance Program
Describes the general guidelines and recommendations for channel inspection and maintenance.

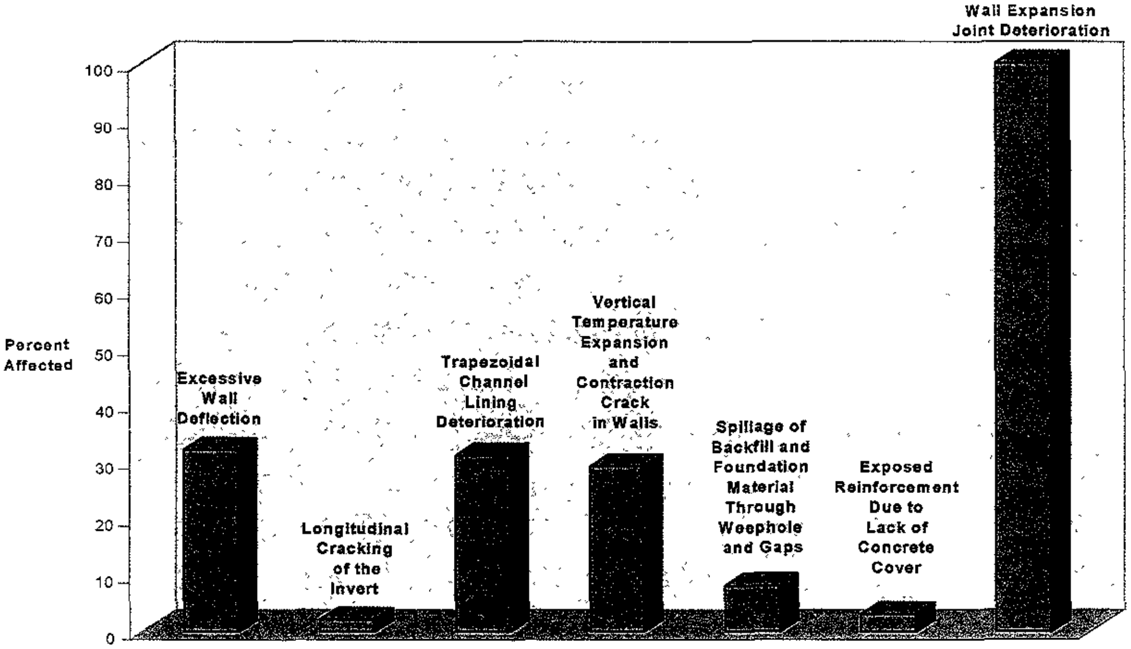
Channel Repair Recommendations, Prioritization and Cost Estimates
Describes the repair recommendations, prioritization and cost estimates for each reach and type of deficiency.

4.1 Conclusions

In general, the worst channel deterioration occurred along Hale Creek in the forms of excessive wall deflection, exposed and corroded rebar, concrete cracks and surface defects. The Permanente Diversion exhibited significant concrete cracking along its entire length, and the upper 700 meters (2,296 feet) of Permanente Creek near the Hale Creek confluence point also exhibits excessive wall deflections and concrete cracks.

As can be seen on the following chart that summarizes the affected lengths by deficiency pattern, wall expansion joint deterioration occurred along 100 percent of the project alignment and was the most prevalent defect. Excessive wall deflection is the second most prevalent deficiency pattern, but also the most severe in terms of its affect on the structural stability of the channels. As shown on the chart, less than 50 percent of the project alignment contained any one of the other deficiencies, which indicates an overall decline in the state of the facility is occurring, but it has not yet affected the majority of the channel structures.

Deficiency Summary by Affected Length of Project Alignment



Conclusions of Test Results

The soil type along Permanente Creek and Permanente Diversion was categorized as clays, which is consistent with the clogged weepholes found in those segments. The soil type along Hale Creek was categorized as sandy, which gives this segment the potential for soil cavities beneath and behind the channel structure. This finding is consistent with the Ground Penetration Radar Tests, which indicated possible cavities or pockets of sandy/gravely lenses saturated with water beneath the invert of the Hale Creek segments.

The tested concrete strength ranged from 27.6 to 55.2 kilopascals (kPa) (4000 to 8000 pounds per square inch [psi]) but was always above the assumed design value of approximately 20.7 kPa (3000 psi), the value for new concrete that has aged only 28 days, which is required for analysis. These higher concrete strengths are typical and expected in aged concrete specimens. The soil corrosivity test results indicated the surrounding soil and water was not significantly corrosive.

In retaining wall designs, the structural design engineer will generally describe the wall type (cantilevered, restrained or tied-back), wall height, live load potential and backfill soil conditions to the geotechnical engineer. Based on this information, the geotechnical engineer will perform a soil-structure analysis and will recommend a design lateral earth loading and lateral live load surcharge loading. However, if there is no geotechnical engineer on the project, the structural engineer may use the default design lateral earth loads specified in the governing code (Uniform Building Code or the Caltrans Bridge Design Specifications, or other). These default design loads usually assume engineered backfill material. Sometimes they have default values for active lateral earth loads (active loads) and for at-rest lateral earth loads (at-rest loads). The Uniform Building Code, which would be the governing code for these walls, only specifies default values for active lateral loads.

Common practice is to assume that most typically sized cantilevered walls can be designed for the lesser active load rather than the higher at-rest load. Walls that are restrained at the top generally have to be designed for the higher at-rest loads. However, if a cantilevered wall is short and stout enough, the wall will not deflect enough to alleviate the higher at-rest loads into the lesser active loads and the wall should be designed for the at-rest loads. Research of the Department of Navy, Foundations and Earth Structures Design Manual 7.2 found that cantilevered walls can usually be designed for the active lateral load if the top of wall can deflect a minimum of 1% of the wall height. Otherwise, the wall will see the higher at-rest loads.

The design engineer probably did not have a geotechnical engineer to develop job specific design loads and correctly by code, used the default, design lateral loads in the code. In doing so, the designer assumes an active load condition and engineered backfill material, which is not consistent with the actual conditions. It was found that this assumption underestimates the actual design lateral loads. However, the designer did design the wall correctly per the governing code even by today's standards.

The Study identified a critical design step that must be analyzed to avoid this underestimation as described below.

4.2 General Concrete Channel Design Recommendations

After defining the deficiency patterns and their underlying causes, deficiency-specific alternatives were developed for two possible scenarios: replacement and repair. General alternatives were developed to address a baseline replacement option, and specific retrofit alternatives were developed for the deficiency patterns that could be addressed with cost-effective repairs to the existing structure. To effectively monitor and repair the deficiencies over time, a recommended inspection and maintenance program was also developed.

Although general design guidelines were developed for the replacement sections, they should also apply to new, future channel structure designs. The guidelines are meant to address the deterioration observed along the Permanente and Hale Creek alignments and should increase the expected life span of new channel structures significantly.

The most significant general design guidelines address the excessive wall deflection deficiency pattern, which prematurely yielded portions of the Permanente and Hale Creek vertical walled channels. The guideline includes an additional design step to ensure the wall yield deflection is at least greater than the wall deflection required to achieve the typically assumed design active earth pressure. Other design guidelines include extending the wall reinforcement development length further into the invert slab and providing for a continuous bottom mat of reinforcement in the invert slab.

This section also includes guidelines that are not necessarily required by code but are specifically advisable for channel structures such as:

- Using epoxy coated rebar for all channel structures where reinforcing is likely to be exposed to significant moisture during the lifetime of the structure, and
- Specifically increasing the temperature reinforcement from the code minimum temperature reinforcement to provide factor of safety of at least 2.

Section 4.4 (Channel Repair Recommendations, Prioritization and Cost Estimates) includes specific recommendations for each deficiency pattern previously identified. The recommendations include replacement alternatives, retrofit alternatives, and maintenance program alternatives, as well as "Accept As Is" alternatives. The "Accept As Is" alternative concedes that deterioration will continue to occur which will ultimately shorten the life of the facility but repairing the deterioration is either impractical and/or not feasible.

Four retrofit alternatives were conceptually developed in addition to the replacement alternatives for the most critical structural concern, excessive wall deflections, which affects the vertical walled channel sections. The four retrofit alternatives developed to address this condition were: 1) vinyl sheet piling, 2) concrete facing with struts, 3) concrete facing with piles, and 4) vertical walled bents.

For the second most critical deficiency, longitudinal cracks in the invert, the vinyl sheet piling or the vertical walled retrofit alternatives can be applied to channels.

Trapezoidal channel lining deterioration was addressed either by a replacement or the "Accept As Is" alternative. Other alternatives for this deficiency were deemed not cost-effective. Similarly, the "Accept As Is" alternative also applies to channel segments with vertical temperature expansion and contraction cracks. Repairing each vertical crack along the project alignment would not be cost effective especially since most segments with vertical temperature cracks also experienced other deficiencies whose retrofit alternative, when eventually implemented, would simultaneously address the temperature cracks. For spillage of backfill and foundation material through weepholes and gaps and for wall expansion joint deterioration, a maintenance program alternative that would periodically check for voids and sinkholes, and backfill them as required is the most effective alternative. The general guideline for spalling of concrete cover is to remove any unsound concrete and patch the deficiency area.

Overall recommendations to address each type of deficiency pattern are included in the following sections.

4.2.1 Excessive Wall Deflections & Longitudinal Cracking of the Invert

To prevent the reoccurrence of excessive wall deflections and longitudinal cracking of the invert, which are found throughout the vertical walled channel sections of Permanente Creek, Hale Creek, and the Permanente Diversion, the following additional design steps and modified details are recommended for future wall designs.

1. For new vertical walled channels assumed to encounter the active lateral pressure distribution, the recommendation is to calculate the yield deflection of the walls and compare it to the deflection required to mobilize the assumed active lateral earth pressure. The deflection required to mobilize the active lateral earth pressure is dependent on the retained soil and the height of the wall. For the vertical wall to encounter the assumed active lateral pressure distribution without deflecting excessively, the yield deflection of the wall must be greater than the deflection required by the retained soil to mobilize the active lateral earth pressure. The greater the difference, the larger the safety factor becomes to ensure that the wall will not deflect excessively in the future (see Figure 9; *Active Earth Pressure Vs. Yield Deflection Relationship*).

2. To account for hydrostatic pressure caused by water behind the walls that cannot drain due to clogged weepholes, the recommendation is to design for an increased design load. This increased design load should account for the saturated soil condition in which the backfill material becomes saturated through backflow during high channel flow. The backflow will induce a hydrostatic head during the period when the channel flow level becomes low again and the saturated backfill slowly drains through the weepholes.

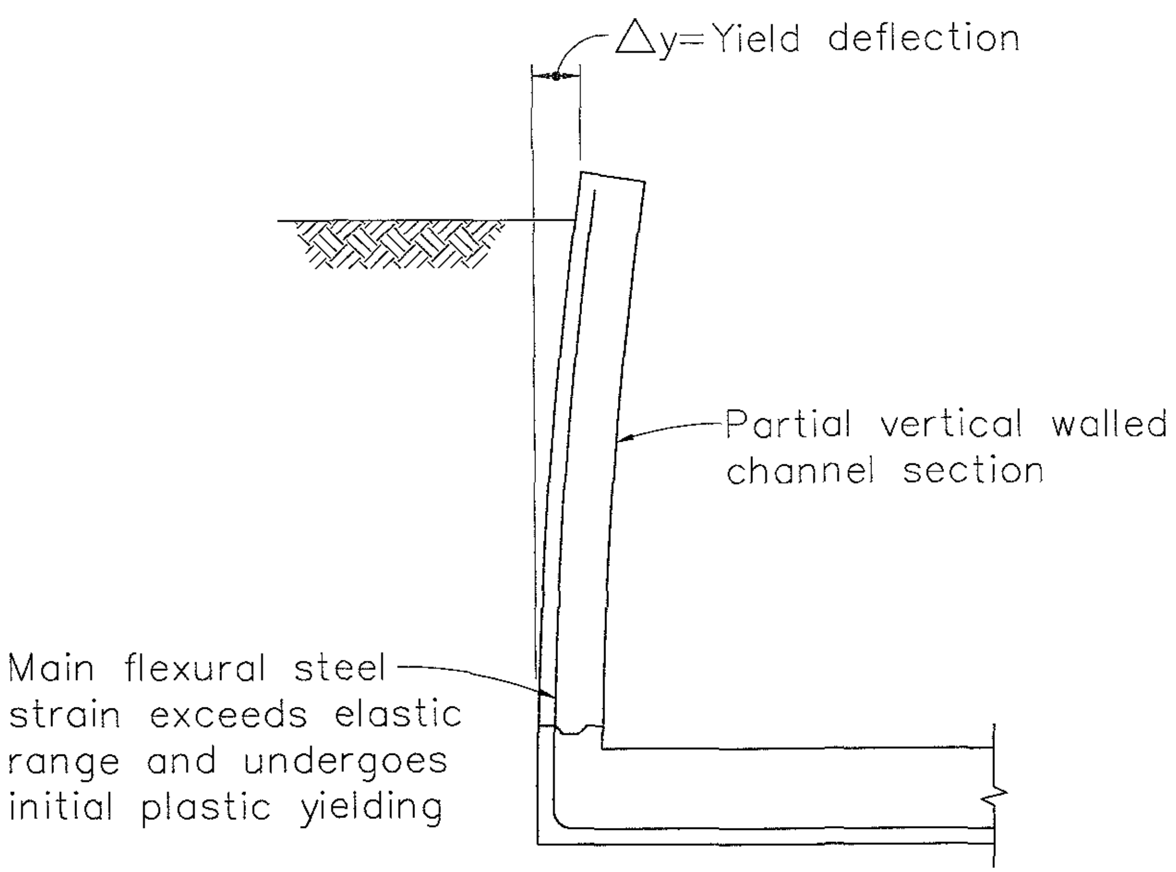
3. To reduce the detrimental impact corrosion has on the main flexural reinforcement of the channel walls, the recommendation is to use epoxy coated reinforcement for all water carrying structures.

4. To reduce the amount of moisture that may come into contact with the main flexural reinforcement via the construction joint, the recommendation is to raise the wall construction joint 150 millimeters (6 inches) above the invert slab, when the invert is formed (see Figure 9; *Active Earth Pressure Vs. Yield Deflection Relationship*).

5. To prevent longitudinal cracking of the invert, the recommendation is to provide reinforcement across the entire width of the invert slab (see Figure 10; *Vertical Walled Channel Recommended Construction Details*).

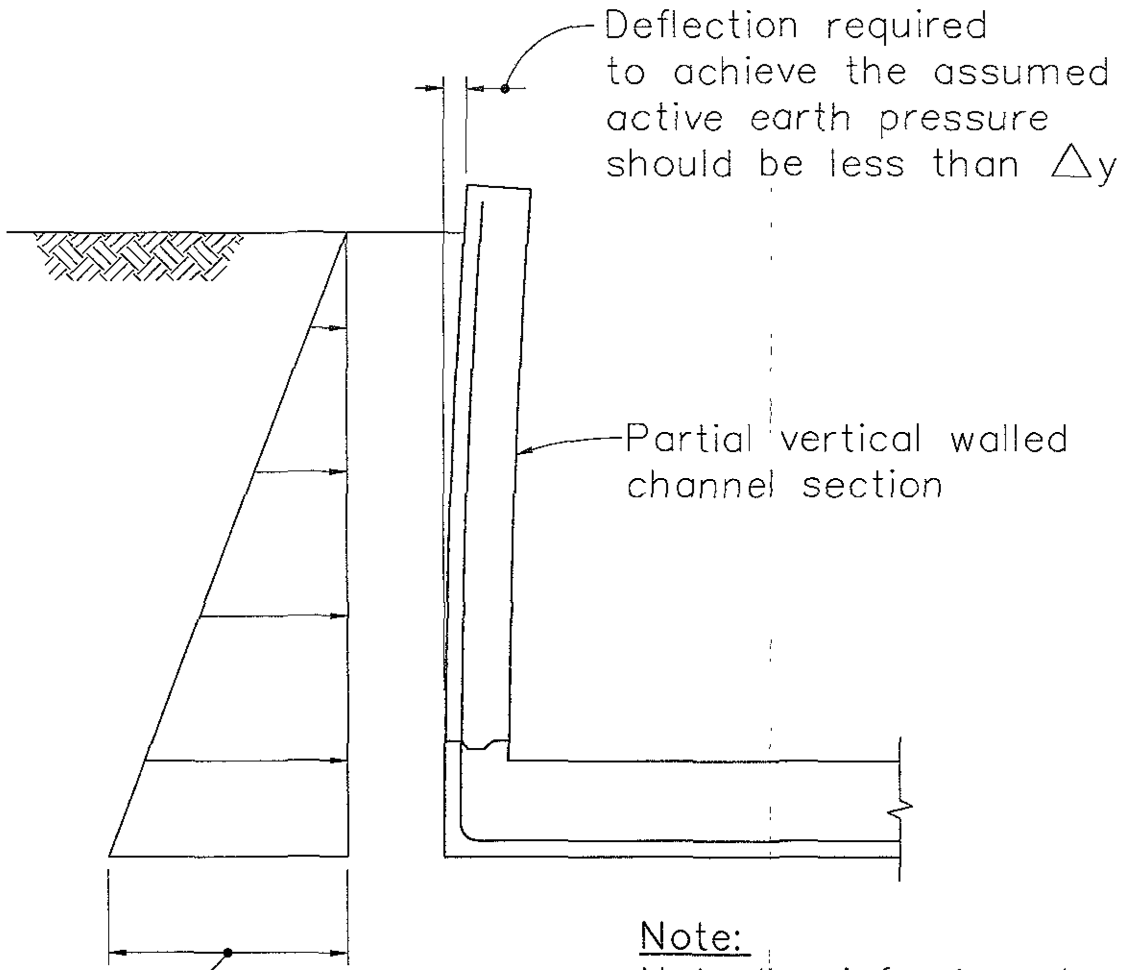
6. To prevent the possibility of reinforcement pulling out of the invert slab, the recommendation is to calculate and provide the hooked development lengths into the invert slab (see Figure 10; *Vertical Walled Channel Recommended Construction Details*).

7. To ensure a well-engineered vertical walled channel section, the recommendation is to follow the quality assurance/quality control practices as outlined in Section 4.2.6 (*Design Quality Assurance/Quality Control Recommendations*) by performing an independent check of the newly designed and detailed structure.


△y=Yield deflection
Partial vertical walled channel section
Main flexural steel strain exceeds elastic range and undergoes initial plastic yielding

Note:
Not all reinforcing shown

SECTION
NTS


Deflection required to achieve the assumed active earth pressure should be less than △y
Partial vertical walled channel section
Lateral soil pressure reduced from at-rest to active pressure once required deflection is achieved

Note:
Not all reinforcing shown

SECTION
NTS

FIGURE 9

BIGGS CARDOSA ASSOCIATES INC
STRUCTURAL ENGINEERS

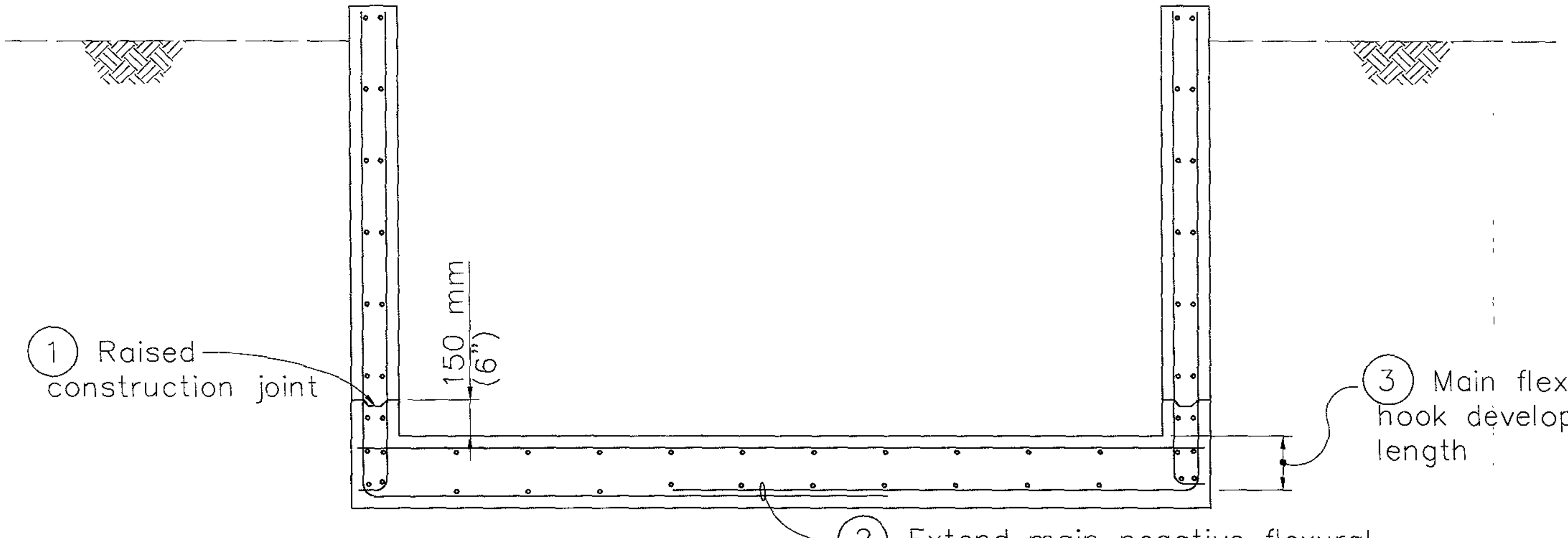
1871 The Alameda, Suite 200
San Jose, California 95126
408-296-5515

BCA

PERMANENTE CREEK
FLOOD CONTROL PROJECT
STRUCTURAL INTEGRITY STUDY

ACTIVE EARTH PRESSURE vs. YIELD DEFLECTION RELATIONSHIP

DESIGNED BY: DRD	DATE: 8/29/00
DRAWN BY: R. MOE	SCALE: NONE
CHECKED BY: RLO	JOB No.: 99029
SHEET 58	
DRAWING No. A 029-9	REV. No.



① Raised construction joint

② Extend main negative flexural steel across the bottom of the invert and lap at the middle, providing for negative moment reinforcing across the entire width of invert

③ Main flexural steel hook development length

SECTION

NTS

FIGURE 10

BIGGS CARDOSA ASSOCIATES INC
STRUCTURAL ENGINEERS

1871 The Alameda, Suite 200
San Jose, California 95126
408-296-5515

PERMANENTE CREEK
FLOOD CONTROL PROJECT
STRUCTURAL INTEGRITY STUDY

VERTICAL WALLED CHANNEL RECOMMENDED CONSTRUCTION DETAILS

DESIGNED BY: DRD	DATE: 8/29/00
DRAWN BY: R. MOE	SCALE: NONE
CHECKED BY: RLO	JOB No.: 99029
SHEET	59
DRAWING No.	REV. No.
A 029-10	

4.2.2 Vertical Temperature Expansion and Contraction Cracks in Walls

To prevent the extensive vertical temperature cracking, which is found throughout the vertical walled channel sections of Permanente Creek, Hale Creek, and the Permanente Diversion, the following additional design steps and modified details are recommended for future wall designs.

1. To reduce the vertical temperature expansion and contraction cracks on the channel walls, the recommendation is to increase the minimum temperature reinforcement required by the code by a safety factor. The minimum code requirement is generally based on the assumption that the expansion joints are approximately 30.5m (100 feet) apart and control joints are approximately 7.6m (25 feet) apart. Also, the code requirement typically applies to soundwalls and retaining walls and not water carrying structures where water is more apt to seep into the expected temperature expansion and contraction cracks. By increasing the temperature reinforcement and adding more steel than the code minimum, the temperature crack widths and lengths can be significantly reduced.

   In Table 3-1 of the publication, *Structural Design of Concrete Lined Flood Control Channels*, document EM 1110-2-2007, April 1995, (http://144.3.144.209/corpsdata/usace/inet/usace-docs/eng-manuals/em1110-2-2007/entire.pdf.), the U.S. Army Corps of Engineers (USACOE) recommends a minimum reinforcing ratio of 0.0040 for longitudinal reinforcing of trapezoidal concrete lined channel walls. This recommendation is slightly more than that of the ACI minimum reinforcing ratio of 0.0018 for each face (or 0.0036 for the wall).

   The existing walls still developed temperature expansion and contraction cracks even though the recommended ACI minimum reinforcing ratio of 0.0018 for each face was used. Therefore, it is recommended that a minimum longitudinal reinforcing ratio in each face be increased to 0.0040 to provide a factor of safety of 2 from the USACOE recommended minimum, which will result in a modified net reinforcing ratio of 0.0080 for a given wall section. Although this will require a marked increase in the longitudinal wall and slab reinforcing, the extensive cracking currently seen justifies the need for the additional steel.

   In addition, because the top of channel walls are typically not restrained by a slab like the bottom of the wall, expansion and contraction movement initiates and is greatest at the top of the wall. To help restrain the top of wall expansion and contraction movement, it is recommended that the longitudinal trim bars be located at the top of the walls at each face and be at least three times larger than the typical longitudinal reinforcing used.

2. To reduce the corrosion of the wall reinforcement due to the vertical temperature cracks, the recommendation is to specify the use of epoxy coated reinforcement for water carrying structures.

3. To ensure a well engineered vertical walled channel section, the recommendation is to perform an independent check of the newly designed and detailed structure.

4.2.3 Trapezoidal Channel Lining Deterioration

To prevent the trapezoidal channel lining deterioration that is found throughout the trapezoidal channel sections of Permanenete Creek, Hale Creek, and the Permanente Diversion, the following additional design steps and modified details are recommended for future wall designs.

1. To reduce the horizontal flexural cracking observed along the channel lining, the recommendation is to design the lining for lateral earth pressures. When a thickened lip is used at the top of the channel lining walls, consider the stiffening effects of that thickened lip on the channel walls (see Figure 11; *Trapezoidal Channel Recommended Construction Details*).

2. To increase the lining capacity in both the vertical and horizontal directions, the recommendation is to construct a waffle type lining (see Figure 11; *Trapezoidal Channel Recommended Construction Details*).

3. To reduce the vertical temperature cracking observed along the channel lining, the recommendation is to increase the longitudinal horizontal minimum temperature reinforcement required by code by a factor of safety of at least 2. Also, provide additional longitudinal trim bars at the top of the walls.

4. To improve the constructibility of the channel lining and extend the life by helping to reduce deterioration, the recommendation is to design a minimum channel slab thickness of at least 150 millimeters (6 inches) (see Figure 11; *Trapezoidal Channel Recommended Construction Details*).

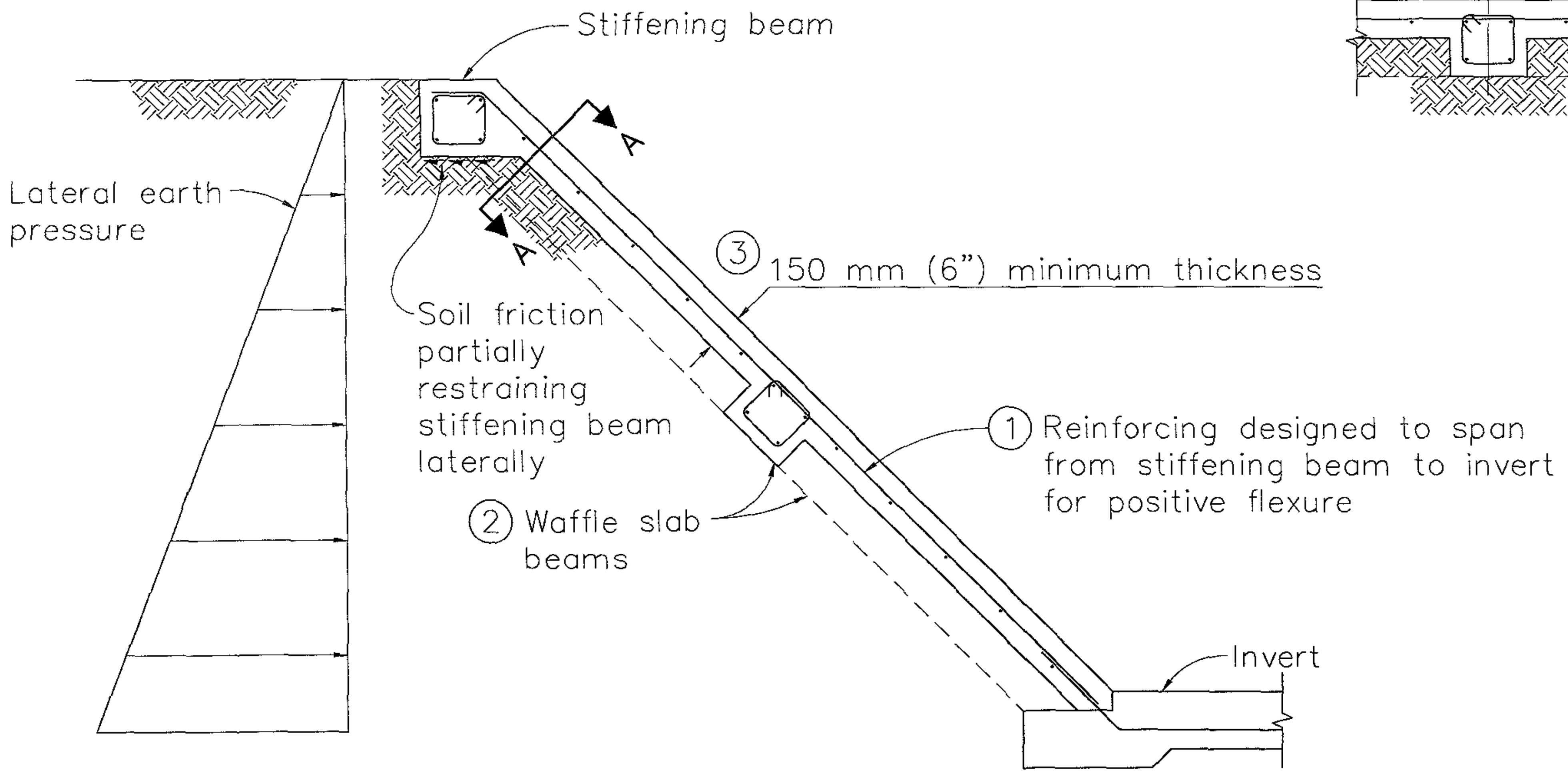
5. To ensure a well-engineered channel lining, the recommendation is to perform an independent check of the newly designed and detailed structure.

4.2.4 Spillage of Backfill and Foundation Material Through Weepholes and Gaps & Wall Expansion Joint Deterioration

To prevent the spillage of backfill and foundation material through weepholes, gaps, and wall expansion joints, the following modified details and design guidelines are recommended for future wall designs.

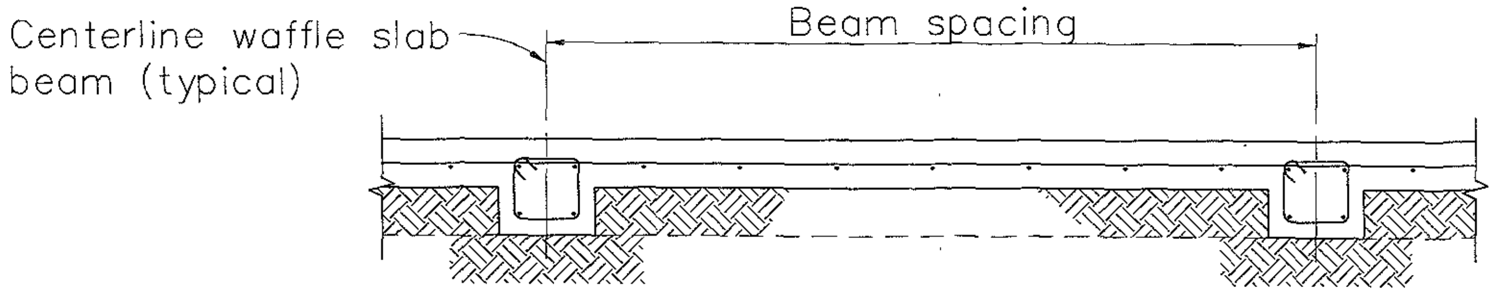
1. To reduce the spillage of backfill and foundation material through the weepholes, better drainage details are required. It is recommended that a continuously perforated plastic pipe in treated permeable base and geocomposite drain against the back of the wall be used. The weepholes should be connected to the perforated pipe at a specified interval (see Figure 12; *Recommended Drainage Details*).

2. To reduce the spillage of backfill and foundation material through the expansion joint gaps, the recommendation is to use a waterstop in addition to the expansion joint filler. Over time, as the expansion joint filler deteriorates, the presence of the waterstop will prevent backfill and foundation material from entering the channel (see Figure 13; *Recommended Wall Joint Details*).


Stiffening beam
Lateral earth pressure
A
A
Soil friction partially restraining stiffening beam laterally
③ 150 mm (6") minimum thickness
① Reinforcing designed to span from stiffening beam to invert for positive flexure
② Waffle slab beams
Invert

Note:
Not all reinforcing shown.

SECTION
NTS



SECTION A-A
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FIGURE 11

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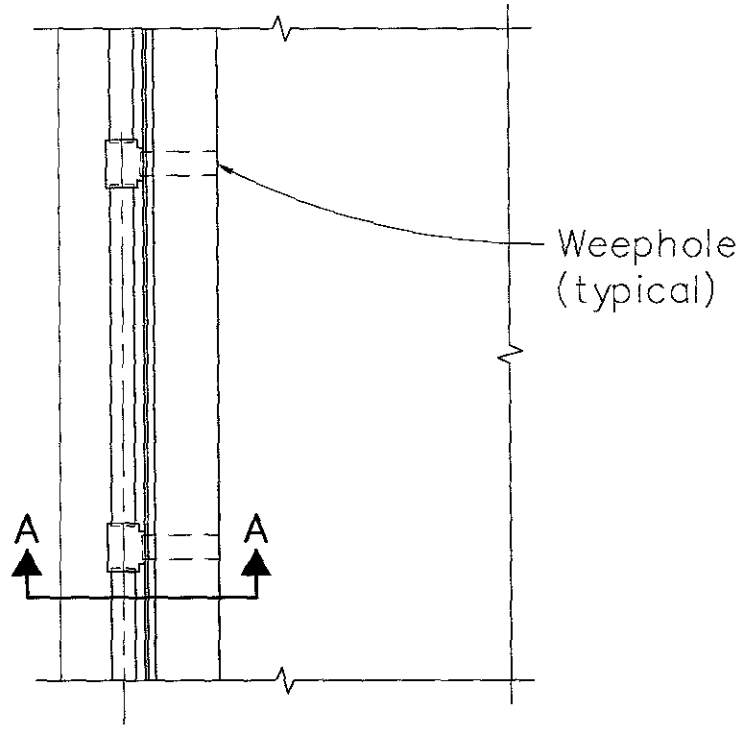
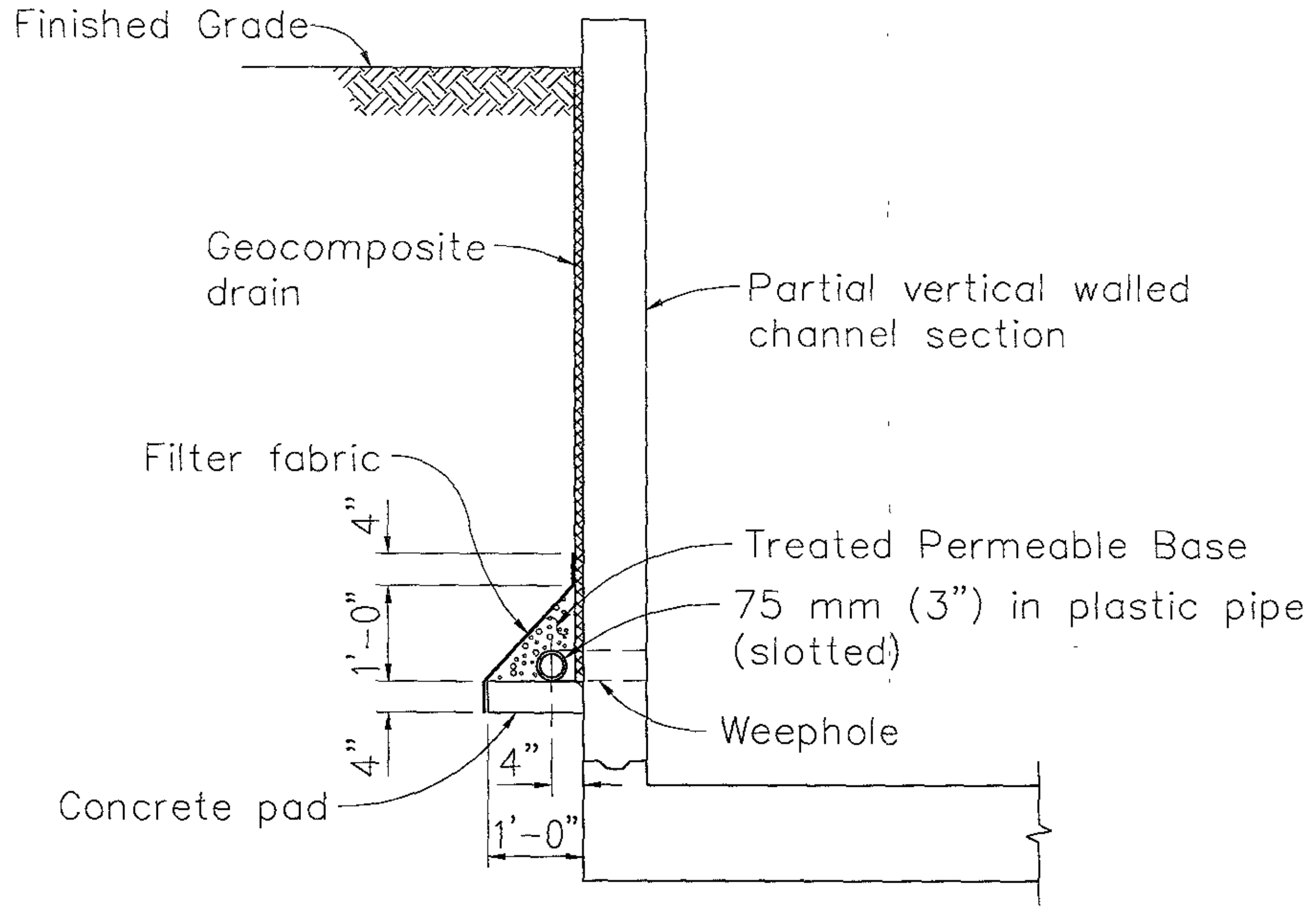
PERMANENTE CREEK
FLOOD CONTROL PROJECT
STRUCTURAL INTEGRITY STUDY

TRAPEZOIDAL CHANNEL RECOMMENDED CONSTRUCTION DETAILS

DESIGNED BY: DRD	DATE: 8/29/00
DRAWN BY: R. MOE	SCALE: NONE
CHECKED BY RLO	JOB No.: 99029
SHEET 62	
A DRAWING No. 029-11	REV. No.



PLAN
NTS



Note:
Reinforcing not shown

SECTION A-A
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FIGURE 12

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San Jose, California 95126
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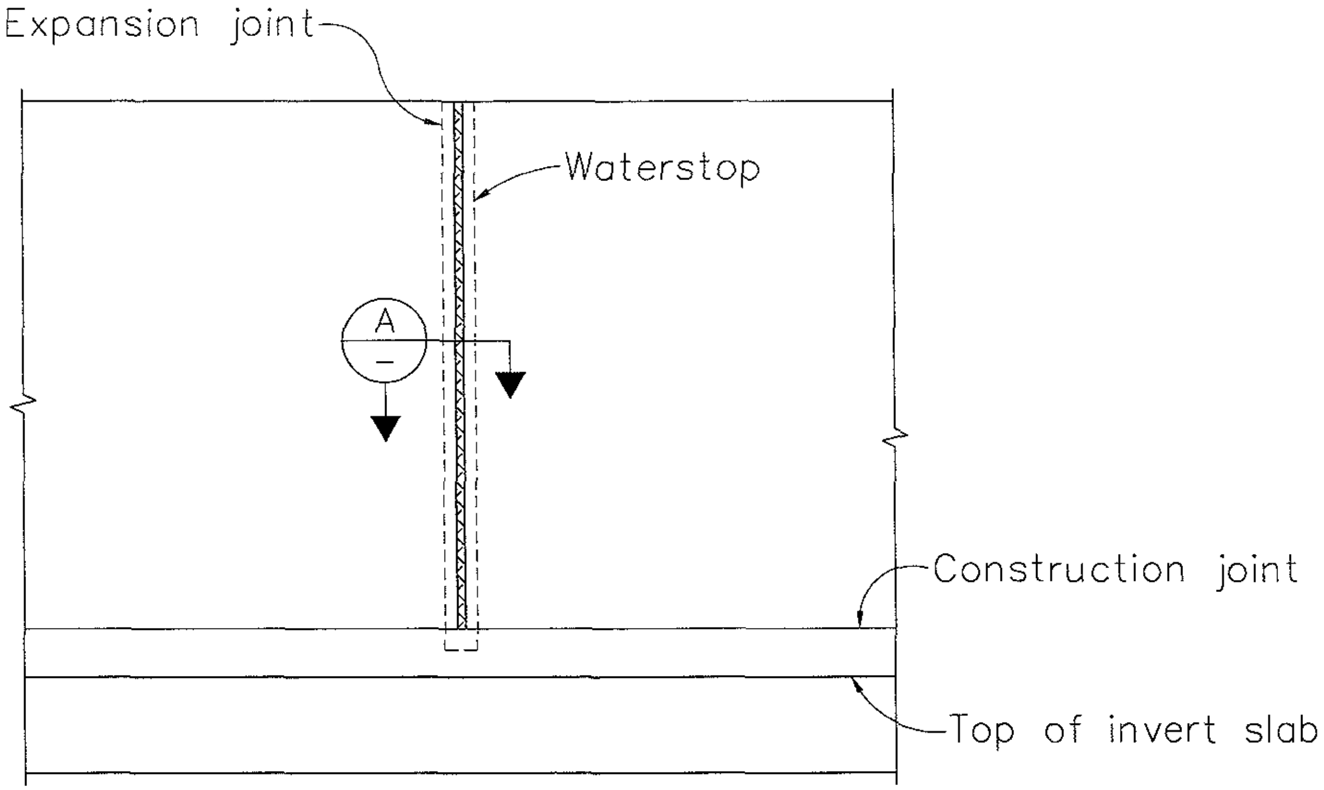
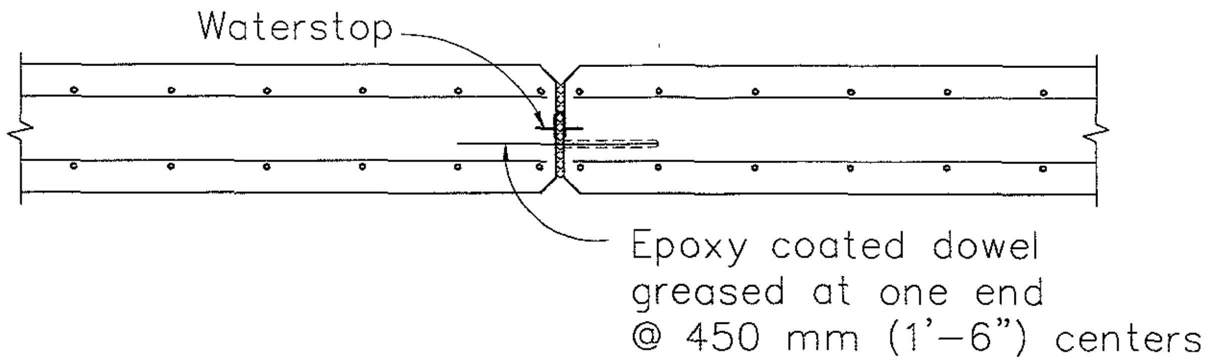
PERMANENTE CREEK
FLOOD CONTROL PROJECT
STRUCTURAL INTEGRITY STUDY

RECOMMENDED DRAINAGE DETAILS

DESIGNED BY: DRD	DATE: 8/29/00
DRAWN BY: R. MOE	SCALE: NONE
CHECKED BY: RLO	JOB No.: 99029
SHEET 63	
DRAWING No.	REV. No.
A 029-12	



WALL ELEVATION
NTS



SECTION A-A
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FIGURE 13

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STRUCTURAL ENGINEERS

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PERMANENTE CREEK
FLOOD CONTROL PROJECT
STRUCTURAL INTEGRITY STUDY

RECOMMENDED WALL JOINT DETAILS

DESIGNED BY: DRD	DATE: 8/29/00
DRAWN BY: R. MOE	SCALE: NONE
CHECKED BY: RLO	JOB No.: 99029
SHEET 64	
DRAWING No.	REV. No.
A 029–13	

3. To ensure a well-engineered channel structure, the recommendation is to perform an independent check of the newly designed and detailed structure.

4.2.5 Exposed Reinforcement Due to Lack of Concrete Cover

To prevent wall reinforcement from being exposed due to lack of concrete cover, the recommendation is to implement more stringent quality assurance procedures during construction. One such quality assurance procedure is to have a full-time inspector during construction to ensure adequate concrete cover over the reinforcing steel.

4.2.6 Design Quality Assurance/Quality Control Recommendations

In addition to considering the findings and conforming to the recommendations in this report, it is also recommended that industry standard QA/QC practices as outlined below be implemented in the design and construction of future facilities:

- Perform an independent design check prior to construction.

- Submit the standard review documents provided by the contractor to the design engineer for a conformance review during the construction process. Such documents typically include rebar cut-sheets, concrete mix designs, material certifications, aggregate gradations, temporary shoring wall design calculations (if required), equipment specifications for heavy construction equipment, etc.

- Implement a full time inspection by a certified International Conference of Building Officials (ICBO) or American Concrete Institute (ACI) special inspector during concrete pours. Test concrete test cylinders for the standard representative volume of concrete poured.

- Implement a part time inspection by a certified ICBO or ACI special inspector during rebar placement. Check rebar sizes, grades, spacing and cover as well as insuring that the pour area and rebar is free of debris and deleterious material directly prior to the concrete pour.

- Implement full time observation by a geotechnical engineer during any pile driving and earthwork operations.

4.3 Channel Inspection and Maintenance Program

This section describes the general guidelines for channel inspection and maintenance. A detailed breakdown of inspection procedures based upon deficiency classification is summarized in Table 5 (*Channel Inspection and Maintenance Guidelines*). An annual maintenance cost is estimated at $50,000 for the entire project alignment based on 180 work hours of a 3-man crew (See Supplement No. 7 "Quantity and Cost Data" for a cost justification breakdown).

Channel inspections and maintenance guidelines are described below.

1. Conduct a visual walk through inspection along the entire project alignment on a semi-annual basis; once in October before the rainy season, and once in April after the rainy season.

Table 5 – Channel Inspection and Maintenance Guidelines

Deficiency	Inspection Guidelines and Recommended Procedures	Deficiency Evaluation, Long-Term Monitoring and Mitigation
Excessive Wall Deflections	➢ Measure and record top-of-wall deflections ♦ Place a plumb bob at top of wall ♦ Measure and record the offset of plumb bob from the base of the wall	➢ Determine the deflection-to-height ratio ➢ If deflection-to-height ratio exceeds 0.175, the wall *must* be repaired (temporarily or permanently) prior to the upcoming rainy season
Longitudinal Cracking of the Invert	➢ Visually inspect the surface of the invert for cracks running roughly parallel to the channel ➢ Record the lengths and widths of any significant cracks observed ➢ Removal of debris may be required to uncover concealed cracks	➢ Maintain a record log of the lengths and widths of representative cracks ➢ Compare the dimensions of the cracks to prior records to evaluate the rate of deterioration ➢ Apply waterproofing sealant over cracks
Trapezoidal Channel Lining Deterioration	➢ Visually inspect the trapezoidal channel walls for cracks and spalls ➢ Identification may be facilitated by noting that vertical cracks often intersect weepholes and horizontal cracks are often located between the lower third and mid-height of the wall ➢ Record the lengths and widths of any significant cracks observed ➢ Note the appearance of new cracks with each inspection	➢ Maintain a record log of the lengths and widths of representative cracks ➢ Compare the dimensions of the spalls and cracks to prior records to evaluate the rate of deterioration ➢ Apply waterproofing sealant over cracks ➢ When major spalling begins to occur, replacement of the channel will be necessary
Vertical Temperature Expansion and Contraction Cracks in Walls	➢ Visually inspect for vertical cracks in the channel walls ➢ Identification may be facilitated by noting that vertical cracks often intersect weepholes ➢ Note the appearance of new cracks with each inspection	➢ Maintain a record log of the lengths and widths of representative cracks ➢ Apply waterproofing sealant over cracks ➢ When major spalling begins to occur, replacement of the channel will be necessary

Table 5 – Channel Inspection and Maintenance Guidelines

Deficiency	Inspection Guidelines and Recommended Procedures	Deficiency Evaluation, Long-Term Monitoring and Mitigation
Spillage of Backfill and Foundation Material Through Weepholes and Gaps	➢ Visually inspect weep holes for spillage of backfill ➢ Prod weepholes to determine if any voids exist behind the walls ➢ Tap walls with a rubber mallet or similar tool to determine if voids exist behind the walls ➢ Visually inspect the soil above the channel walls for evidence of sinkholes (sinkholes are indicative of voids)	➢ Fill any voids that are identified
Exposed Reinforcement Due to Lack of Concrete Cover	➢ Visually inspect the channel walls for exposed rebar ➢ Special attention should be paid to locations where concrete has spalled, cracked or otherwise separated ➢ This deficiency generally occurs at the bases of walls	➢ Patch spalled concrete per the recommendations made in the study
Wall Expansion Joint Deterioration	➢ Visually inspect wall expansion joints for deterioration or complete absence of filler material. This deficiency is often accompanied by concrete popouts, spillage of backfill and/or exposed dowels	➢ Determine if voids exist behind walls where spillage occurs ➢ Fill any voids that are identified

2. Keep record logs of measurements, visual assessments and work performed during each walk through.

Pre-Rainy Season Walk Through

The pre-rainy season walkthrough inspection is intended to serve as a cursory inspection of the project alignment. The primary purpose of this inspection is to check for sections that may be in danger of significant deterioration or collapse during the upcoming rainy season. Items to be monitored and checked are as follows:

1. Spot checks of segments designated as severely deflected vertical walled channels:

   --Measure and record top of wall deflections.

   --Initiate temporary repair measures for wall segments with deflection-to-height ratios greater than 0.175 that are considered to be in danger of collapse during the upcoming rainy season.

2. Remove vegetation growth and debris within the channel and clean weepholes.

Post-Rainy Season Walk Through

The post-rainy season walk through inspection is intended to serve as a more detailed assessment of the project alignment.

1. Measure and record top of wall deflections for all vertical walled channel segments.

2. Review project alignment for additional deficiencies not already noted and update records.

3. Re-measure and record existing deterioration (cracks, spalls and gaps). Patch significant spalls and waterproof cracks with sealant.

4. Inspect project alignment for sinkholes and soil voids behind the channel walls.

5. Prod weepholes and gaps to determine whether formation of voids behind the walls has occurred.

The estimated annual cost of implementing an inspection and maintenance program is $50,000 per year for the entire project alignment.

4.4 Channel Repair Recommendations, Prioritization, and Cost Estimates

This section includes specific recommendations for each deficiency pattern previously identified. The recommendations include replacement alternatives, retrofit alternatives, maintenance program alternatives, as well as "Accept As Is" alternatives. The “Accept As Is” alternative concedes that deterioration will continue to occur which will ultimately shorten the life of the facility but repairing the deterioration is either impractical and/or not feasible.

4.4.1 Repair Recommendations

For each deficiency there is a corresponding course of action for its repair. Some deficiencies have multiple recommended repair alternatives while others do not. The repair recommendation(s) for each deficiency is listed below. Table 6 (*Repair Alternative Cost Summary*) breaks down the amount of channel segment that is recommended to be repaired in 0 to 5 years, 5 to 10 years, 10 to 15 years, and greater than 15 years and summarizes the associated costs and added life expectancy for the two main deficiencies (excessive wall deflections and longitudinal cracking of the invert). Quantities of materials for completing repairs and associated cost data are provided as Supplement 7 to this report (*Quantity and Cost Data*).

Table 6 - Repair Alternative Cost Summary

(Applicable to Excessive Wall Deflections & Longitudinal Cracking of the Invert Deficiencies Only)

Structures That Need Attention within 0-5 years

Length of Channel Affected	***Repair Option** (see notes below for repair designation)*				
	1	2	3	4	5
858 meters (2815 ft)	**$5.00 M**	**$2.91 M**	**$1.43 M***	**$2.83 M***	**$0.38 M**
Increased Life Expectancy	**80 Yrs**	**50 Yrs**	**50 Yrs**	**50 Yrs**	**20-25 Yrs**

Structures That Need Attention within 5-10 years

Length of Channel Affected	***Repair Option** (see notes below for repair designation)*				
	1	2	3	4	5
1044 meters (3425 ft)	**$3.36 M**	**$3.79 M**	**$1.54 M**	**$3.70 M**	**$0.42 M**
Increased Life Expectancy	**80 Yrs**	**50 Yrs**	**50 Yrs**	**50 Yrs**	**20-25 Yrs**

Structures That Need Attention within 10-15 years

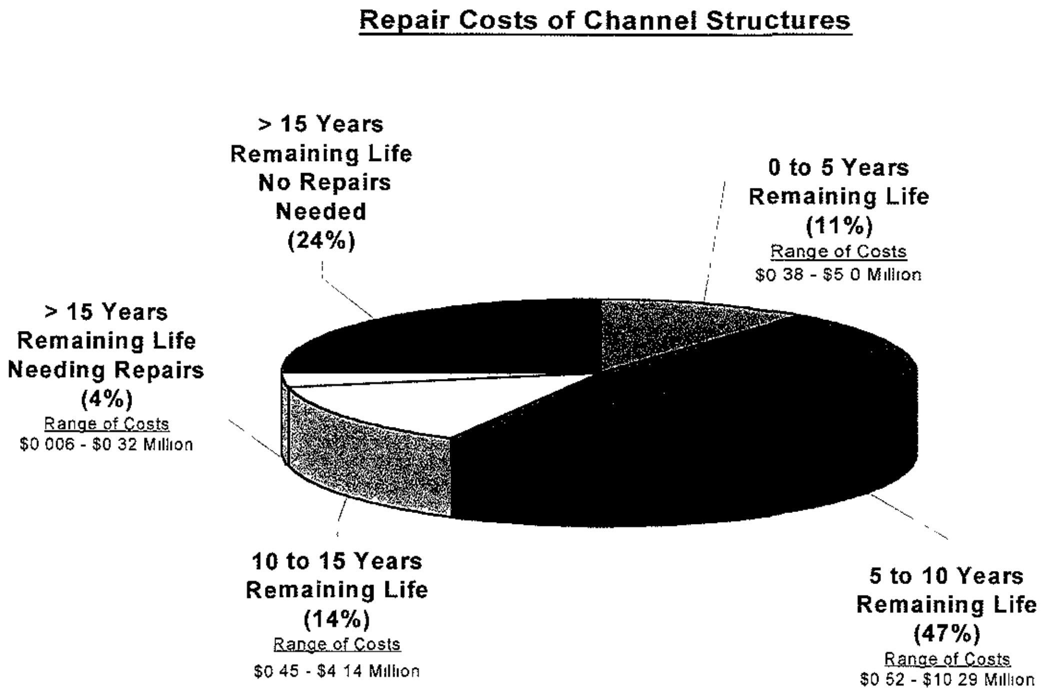
Length of Channel Affected	***Repair Option** (see notes below for repair designation)*				
	1	2	3	4	5
1103 meters (3619 ft)	**$3.66 M**	**$4.14 M**	**$1.68M**	**$4.03 M**	**$0.45 M**
Increased Life Expectancy	**80 Yrs**	**50 Yrs**	**50 Yrs**	**50 Yrs**	**20-25 Yrs**

Notes:

Repair Option 1:	Total redesign and replacement of the existing concrete channel section
Repair Option 2:	Installation of vinyl sheet piling
Repair Option 3:	Installation of a concrete facing with a horizontal strut
Repair Option 4:	Installation of a concrete facing attached to concrete piles
Repair Option 5:	Installation of a concrete vertical walled bent

* For reach number 'H 5B' where Longitudinal Cracking of the Invert occurs, Vinyl Sheet Piling is assumed.

The following chart illustrates estimated remaining life expectancies for each portion of the project alignment and summarizes the associated range of costs for repair or replacement to increase the life expectancies. As shown on the chart, 76 percent of the project alignment requires some sort of repair or replacement in the next 15 years to maintain its structural stability. Based on the estimates, greater than half of the facility's channel structures have less than 15 years of remaining life.



Repair Costs of Channel Structures

Note: Annual Maintenance Cost is estimated at $50,000 for the entire project alignment (See Section-4.3 "Channel Inspection and Maintenance Program" for expanded details of the Inspection and Maintenance Program).

4.4.1.1 Excessive Wall Deflections

For walls with excessive deflections, the existing walls are incapable of adequately resisting the expected loads. To curtail or eliminate the excessive wall deflections, five recommended repair alternatives were developed. Depending on the severity of the wall deflections and construction spatial restraints, one recommended repair alternative may be more appropriate than the other. These recommended alternatives were developed to meet the restrictive right-of-way limitations observed at the locations along the creek alignment where the deficiency pattern occurred. The right-of-way required for the alternatives recommended varies from 0.3 to 1.5 meters (1 to 5 feet).

1. The first repair alternative is the total redesign and replacement of the channel section.

2. The second repair alternative is to install vinyl sheet piling behind the existing vertical walled channel section. If the existing walls are determined to be unstable even without the lateral earth loads, remove the existing walls and replace them by constructing a facing wall inside the channel to maintain a continuous inside channel face for the channel water flow (see Figure 14; *Conceptual Retrofit: [Alternative A] Vinyl Sheet Piling*).

3. The third repair alternative is to construct a reinforced concrete facing wall in front of the existing deflected walls. The facing wall would be epoxy doweled into the invert slab at the bottom, extended beyond the top of existing wall as required, and supported at the top with a concrete strut that traverses the channel at regular intervals (see Figure 15; *Conceptual Retrofit: [Alternative B] Concrete Facing with ~~Structure~~* Struts).

4. The fourth repair alternative is to construct a reinforced concrete facing wall in front of the existing deflected walls. The facing wall would be epoxy doweled into the invert slab at the bottom, extended beyond the top of existing wall as required, and supported at the top by a concrete cap beam structurally tied to piles behind the existing vertical walled channel section. The piles behind the existing sections would be spaced at regular intervals (see Figure 16; *Conceptual Retrofit: [Alternative C] Concrete Facing with Piles*).

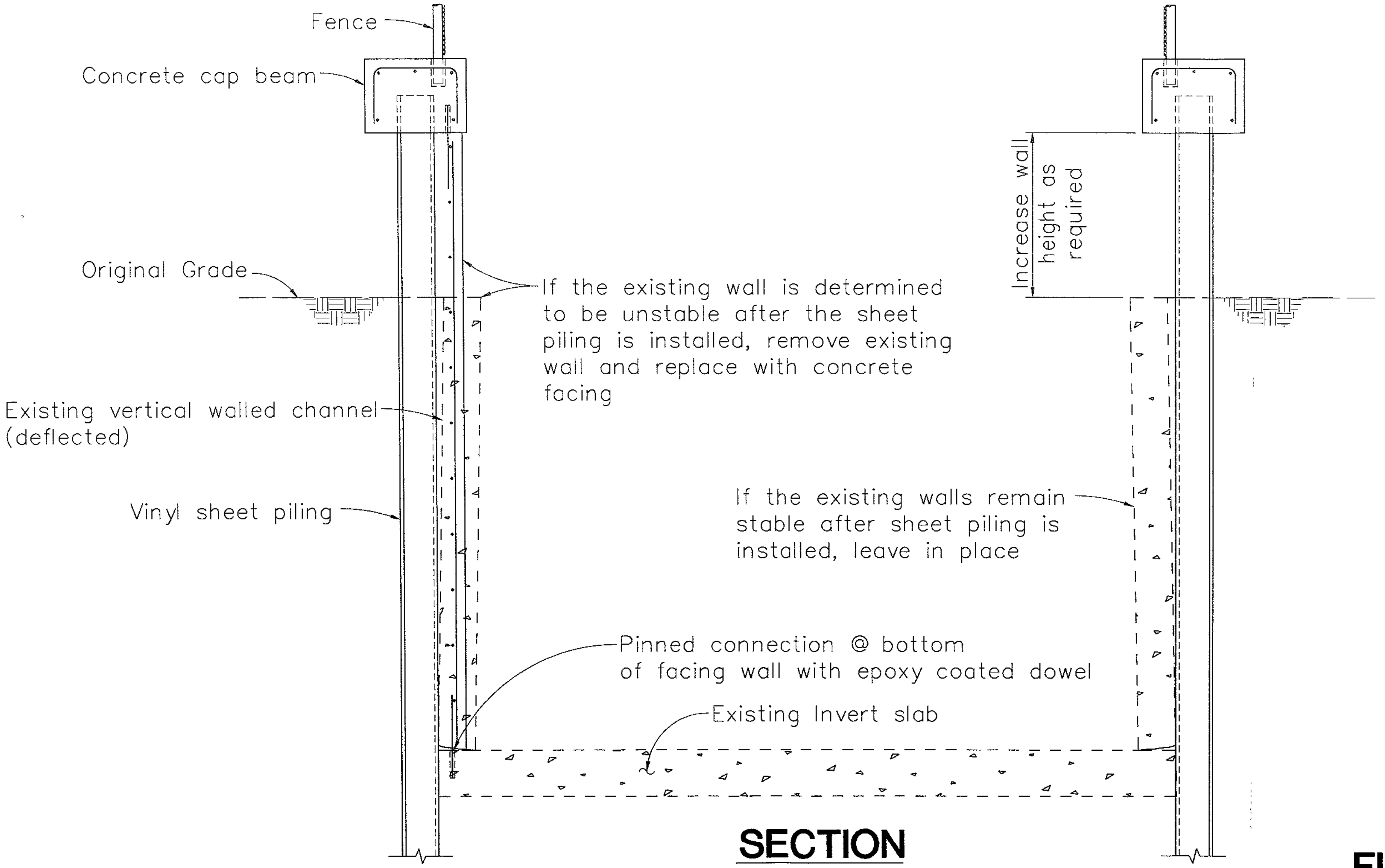
5. The fifth repair alternative is to construct vertical walled bents at regular intervals and utilize the existing concrete walls and slab by attaching the existing concrete to the vertical walled bents with dowels. Sections will have to be cut and removed at regular intervals and soil will have to be excavated to construct the vertical walled bents. The inside face of the vertical walled bent will be casted flushed with the existing channel surface (see Figure 17; *Conceptual Retrofit: [Alternative D] Vertical Walled Bent*).

4.4.1.2 Longitudinal Cracking of the Invert

For longitudinal cracking of the invert, rotation is possible at the longitudinal crack. This rotation leads to excessive wall deflection. To curtail or eliminate excessive wall deflections due to longitudinal cracking of the invert, three recommended repair alternatives have been developed. These recommended alternatives were developed to meet the restrictive right-of-way limitations observed at the locations along the creek alignment where the deficiency pattern occurred. The right-of-way required for the alternatives recommended varies from 0.3 to 1.5 meters (1 to 5 feet).

1. The first alternative is the total redesign and replacement of the channel section.

2. The second alternative is to install vinyl sheet piling behind the existing vertical walled channel section. If the existing walls are determined to be unstable even without the lateral earth loads, remove the existing walls and replace them by constructing a facing wall inside the channel to maintain a continuous inside channel face for the channel water flow. The longitudinal crack can be sealed with an epoxy sealant to minimize further corrosion to the invert reinforcing (see Figure 14; *Conceptual Retrofit: [Alternative A] Vinyl Sheet Piling*).


Fence
Concrete cap beam
Original Grade
Existing vertical walled channel (deflected)
Vinyl sheet piling
If the existing wall is determined to be unstable after the sheet piling is installed, remove existing wall and replace with concrete facing
Increase wall height as required
If the existing walls remain stable after sheet piling is installed, leave in place
Pinned connection @ bottom of facing wall with epoxy coated dowel
Existing Invert slab

SECTION

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FIGURE 14

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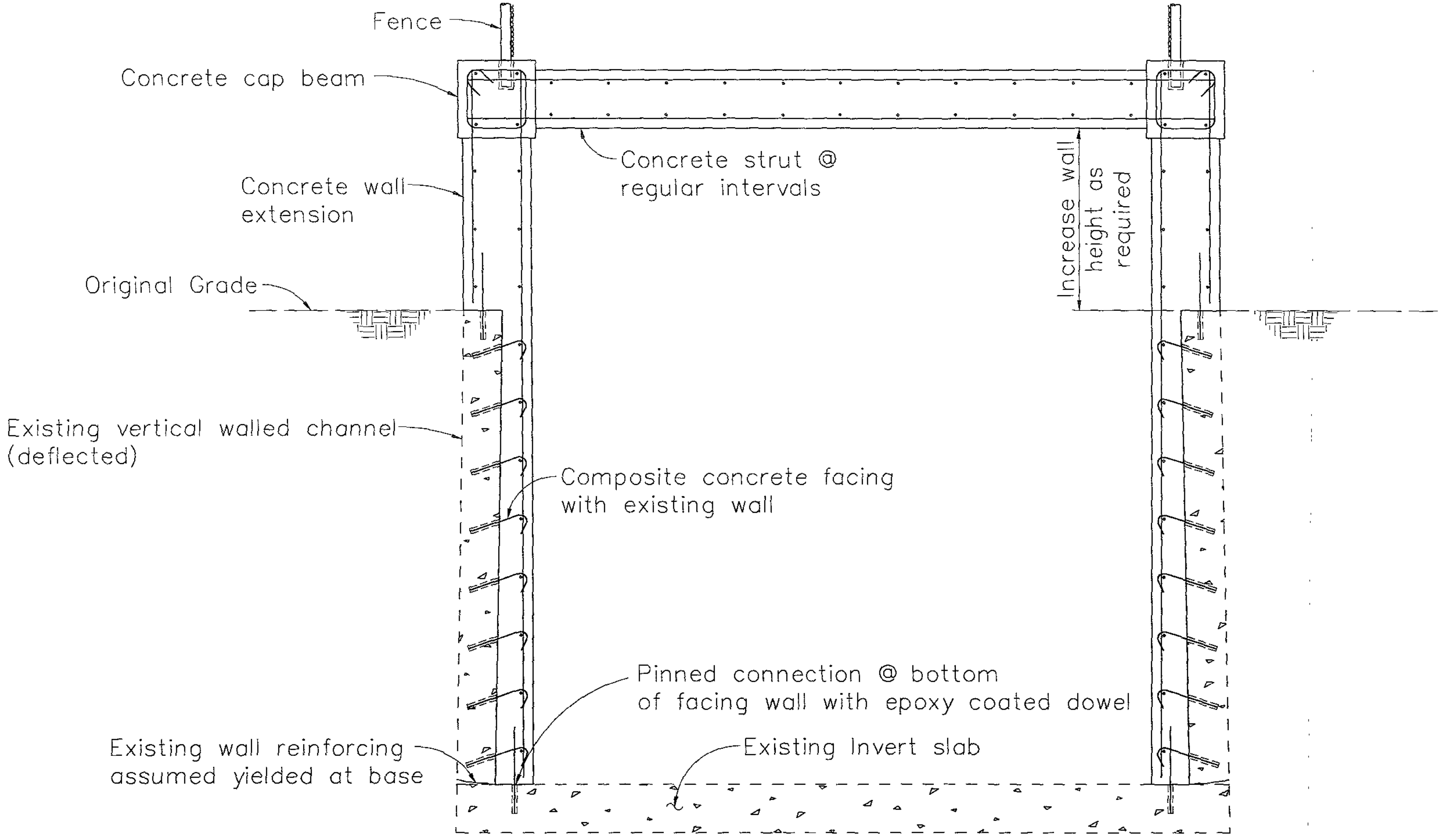
San Jose, California 95126
408-296-5515

PERMANENTE CREEK
FLOOD CONTROL PROJECT
STRUCTURAL INTEGRITY STUDY

CONCEPTUAL RETROFIT
(ALTERNATIVE A)
VINYL SHEET PILING

DESIGNED BY: DRD	DATE: 8/29/00
DRAWN BY: T. SIMMONS	SCALE: NONE
CHECKED BY: RLO	JOB No: 99029
SHEET 72	
DRAWING No.	REV. No.
A 029-14	


Fence
Concrete cap beam
Concrete strut @ regular intervals
Concrete wall extension
Increase wall height as required
Original Grade
Existing vertical walled channel (deflected)
Composite concrete facing with existing wall
Pinned connection @ bottom of facing wall with epoxy coated dowel
Existing wall reinforcing assumed yielded at base
Existing Invert slab

SECTION
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FIGURE 15

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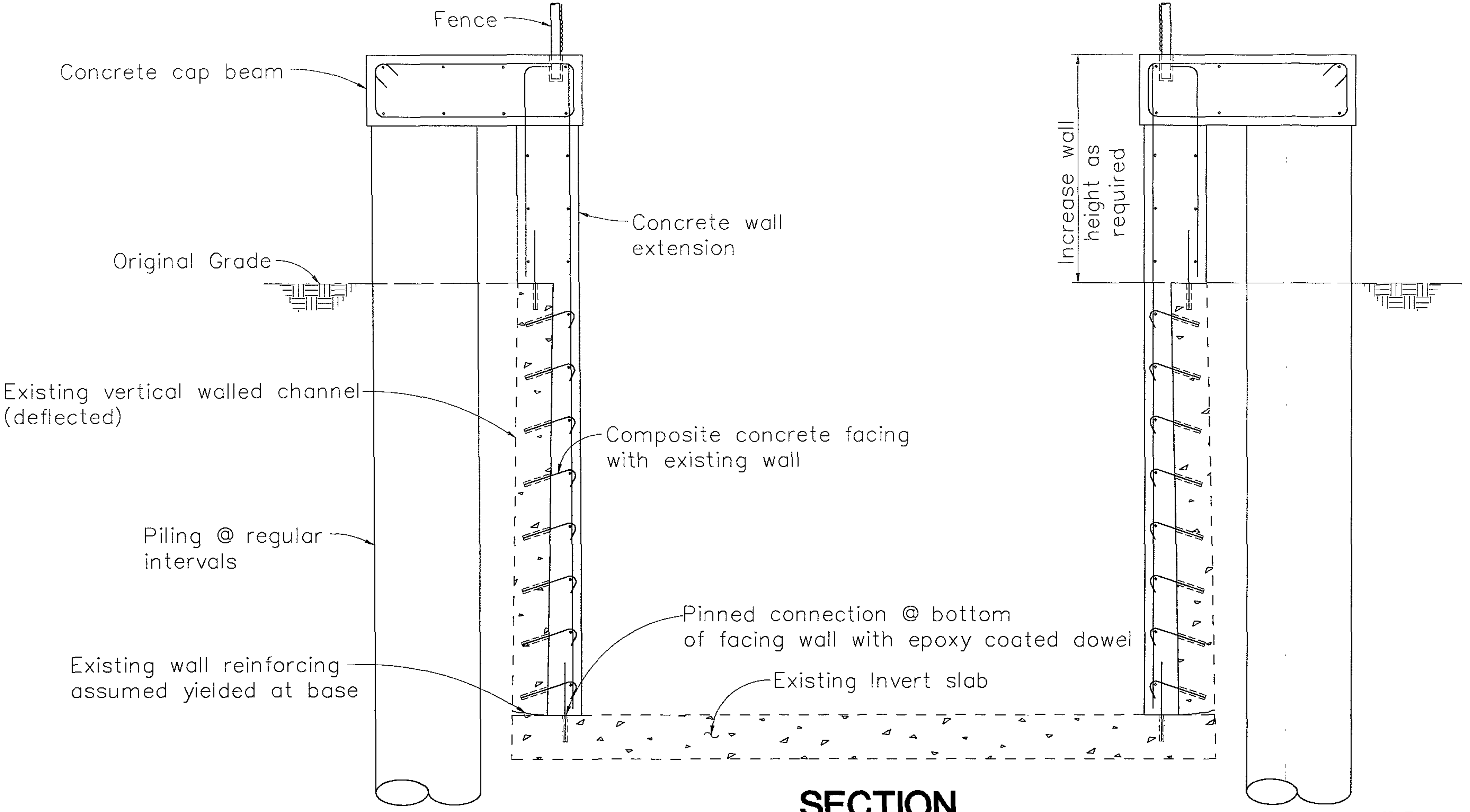
PERMANENTE CREEK
FLOOD CONTROL PROJECT
STRUCTURAL INTEGRITY STUDY

CONCEPTUAL RETROFIT
(ALTERNATIVE B)
CONCRETE FACING W/ STRUT

DESIGNED BY: DRD
DATE: 8/29/00
DRAWN BY: T. SIMMONS
SCALE: NONE
CHECKED BY: RLO
JOB No.: 99029
SHEET 73
DRAWING No. A 029-15
REV. No.


Fence
Concrete cap beam
Concrete wall extension
Increase wall height as required
Original Grade
Existing vertical walled channel (deflected)
Composite concrete facing with existing wall
Piling @ regular intervals
Pinned connection @ bottom of facing wall with epoxy coated dowel
Existing wall reinforcing assumed yielded at base
Existing Invert slab

SECTION
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FIGURE 16

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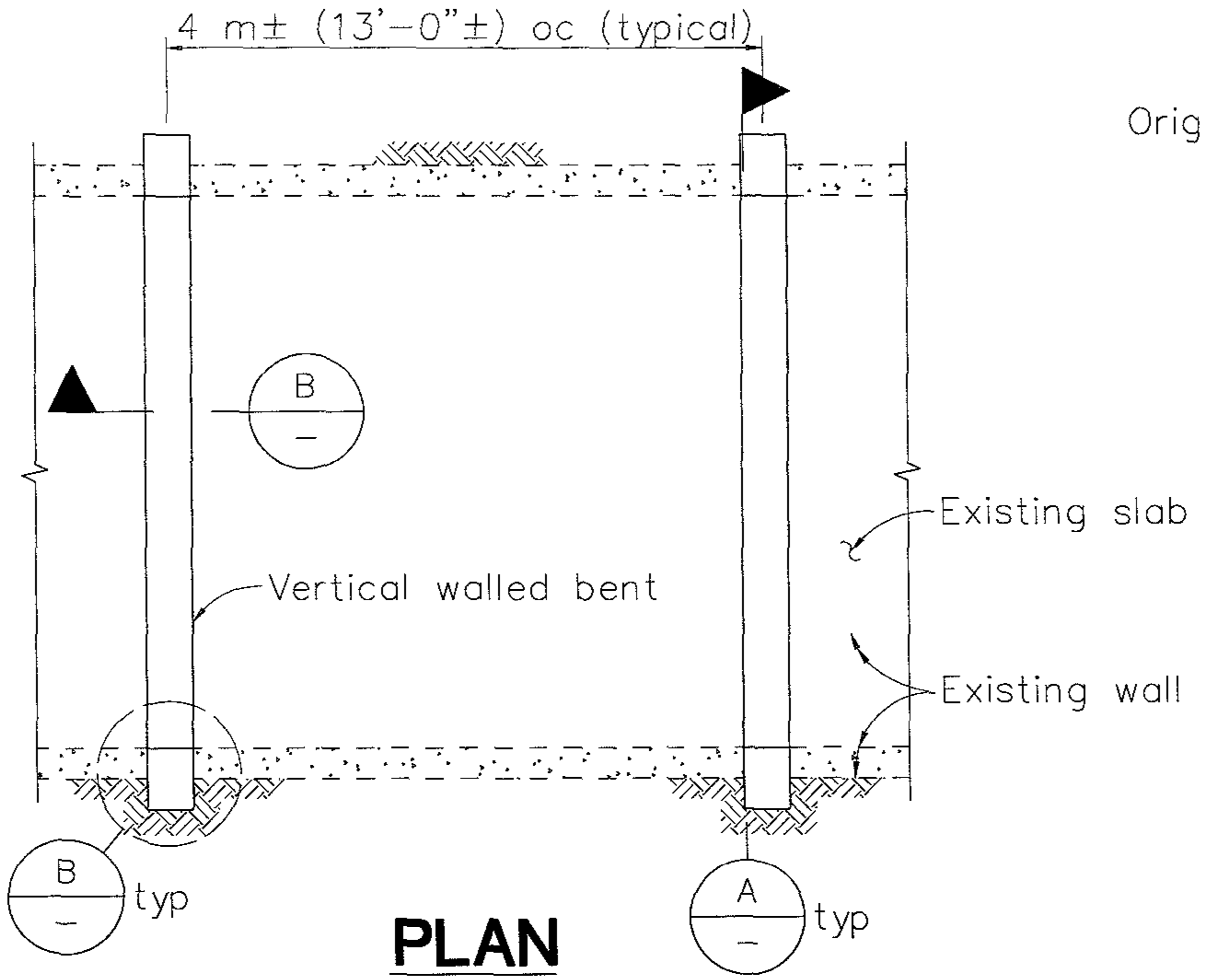
PERMANENTE CREEK
FLOOD CONTROL PROJECT
STRUCTURAL INTEGRITY STUDY

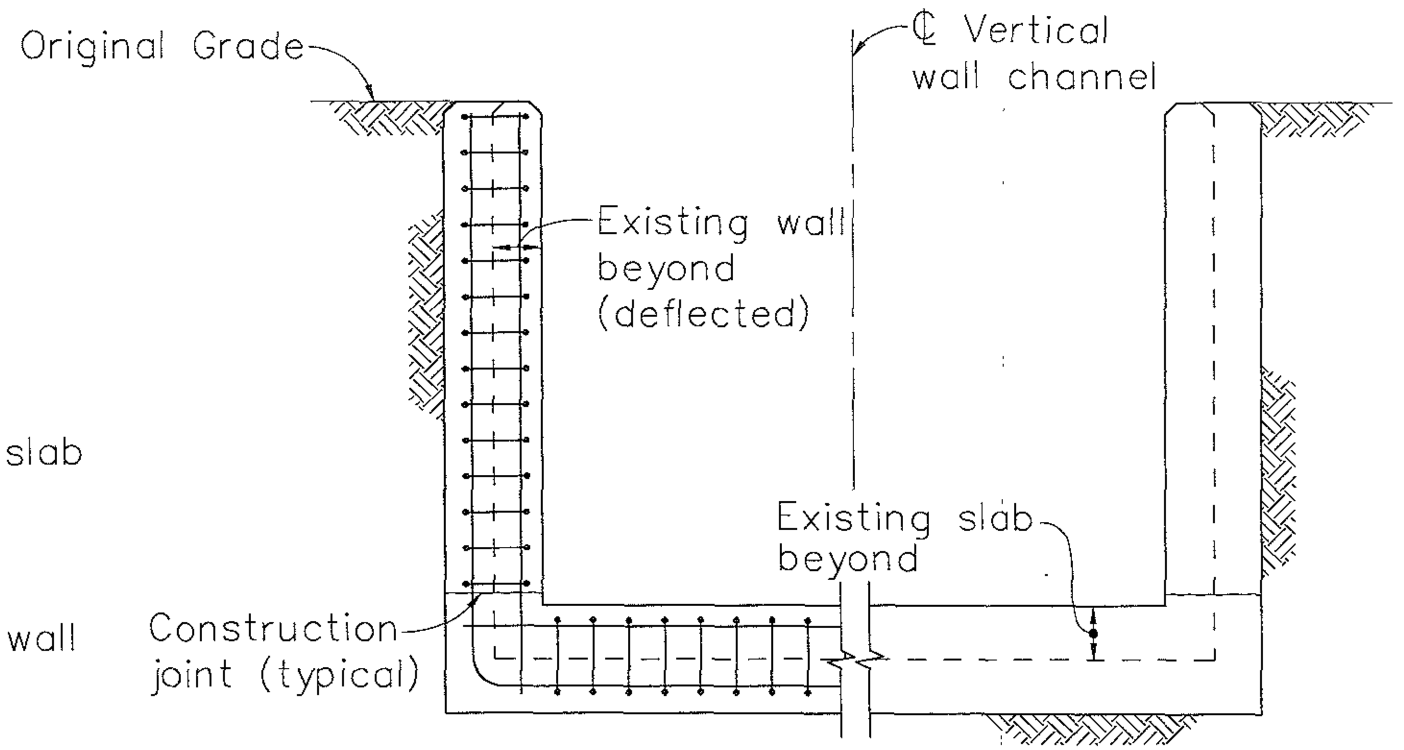
CONCEPTUAL RETROFIT
(ALTERNATIVE C)
CONCRETE FACING W/ PILES

DESIGNED BY: DRD	DATE: 8/29/00
DRAWN BY: T. SIMMONS	SCALE: NONE
CHECKED BY: RLO	JOB No.: 99029
SHEET 74	
DRAWING No.	REV. No.
A 029-16	



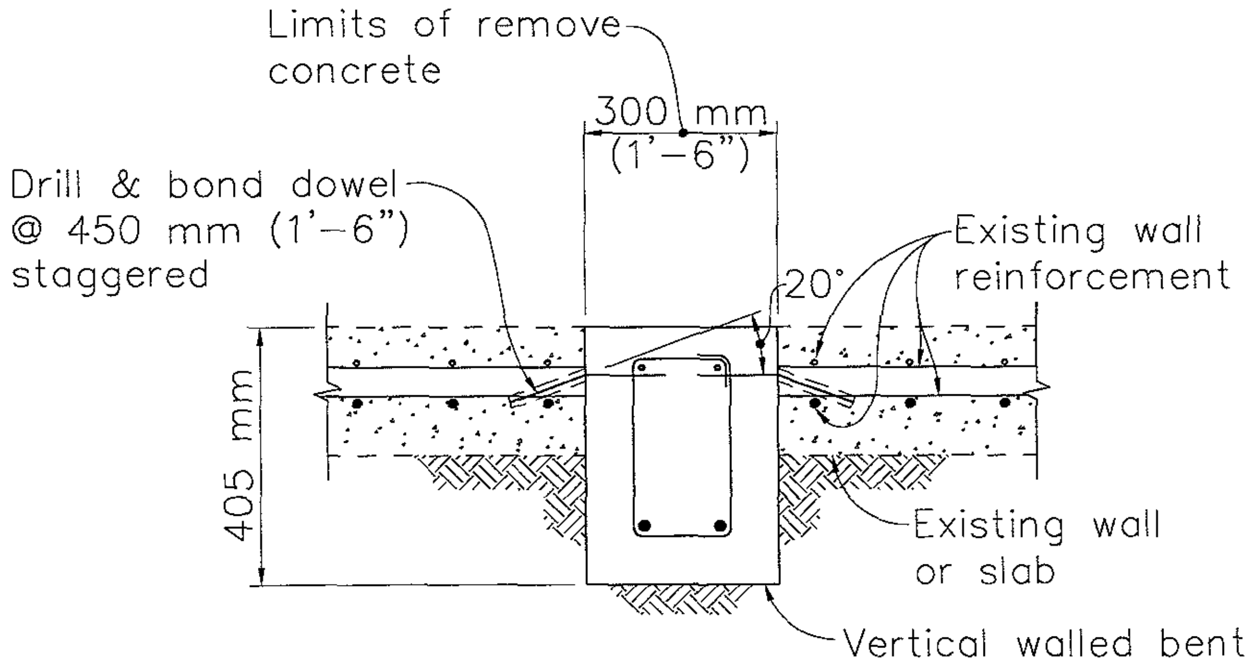
PLAN

NTS



SECTION A-A

NTS



SECTION B-B

NTS

FIGURE 17

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ASSOCIATES INC
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San Jose, California 95126
408–296–5515

PERMANENTE CREEK
FLOOD CONTROL PROJECT
STRUCTURAL INTEGRITY STUDY

CONCEPTUAL RETROFIT
(ALTERNATIVE D)
VERTICAL WALLED BENT

DESIGNED BY: KDC
DATE: 8/29/00
DRAWN BY: NMB
SCALE: NONE
CHECKED BY: RLO
JOB No.: 99029
SHEET 75
DRAWING No. A 029–17
REV. No.

3. The third alternative is to construct vertical walled bents at regular intervals and utilize the existing concrete walls and slab by attaching the existing concrete to the vertical walled bents with dowels. Sections will have to be cut and removed at regular intervals and soil will have to be excavated to construct the vertical walled bents. The inside face of the vertical walled bent will be casted flushed with the existing channel surface (see Figure 17; *Conceptual Retrofit: [Alternative D] Vertical Walled Bent*).

4.4.1.3 Trapezoidal Channel Lining Deterioration

For the trapezoidal channel lining deterioration, concrete delamination and loss of lining is inevitable. Two recommended repair alternatives were developed, but only one of these alternatives will curtail or eliminate the lining deterioration. It was assumed that the repair of the channel lining may be done within the channel, therefore there will be no right-of-way issues.

1. The first repair alternative would be the total redesign and replacement of the channel section.

2. The second alternative would be to not fix the channel lining at all. By not fixing the channel lining you accept the fact that the life expectancy of the channel lining is reduced and not the expected 50 to 60 years from construction but 45-50 years. Therefore, without fixing the channel lining, the estimated remaining life is approximately 5 to 10 years.

4.4.1.4 Vertical Temperature Expansion and Contraction Cracks in Walls

Vertical temperature expansion and contraction cracks in the walls allow water to corrode the wall reinforcement. Corrosion of the wall reinforcement reduces the performance of the walls, however the lack of severity of the rebar corrosion due to these cracks indicates that these walls are not of imminent structural concern for collapse. Repairing each vertical crack along the project alignment would be impractical and quite expensive. Other than the repair alternatives recommended for excessive wall deflections, which would simultaneously address this deficiency, the fact that the vertical cracks are reducing the performance and life expectancy of the walls is recommended to be accepted.

4.4.1.5 Spillage of Backfill and Foundation Material through Weepholes and Gaps

Spillage of backfill and foundation material through weepholes and gaps creates voids and possibly sinkholes behind the channel linings and walls. To remediate the probability of voids or sinkholes from forming behind the channel linings and walls, it is recommended that a maintenance program be implemented that would inspect the channel and fill any voids found along the project alignment (Section 4.3 - Channel Inspection and Maintenance Program). In addition, it is recommended that any spalled concrete adjacent to an expansion joint that may allow backfill or foundation material to enter the channel be grouted. The general area should be cleaned of unsound concrete, sandblasted before patching with new grout/concrete.

4.4.1.6 Exposed Reinforcement Due to Lack of Concrete Cover

The spalling of concrete cover, which is due to poor construction quality control, has led to the accelerated corroding of the wall reinforcement. To slow down the corrosion of the wall reinforcement, concrete patching by chipping out the unsound concrete, sandblasting and casting of a new concrete facing is recommended.

4.4.1.7 Wall Expansion Joint Deterioration

Wall expansion joint deterioration, which is expected to occur during the service life of the channel, creates gaps between adjacent channel sections allowing backfill or foundation material to enter the channel. To remediate the probable voids or sinkholes behind the channel walls and linings, the implementation of a maintenance program that would inspect the channel and fill any voids found along the project alignment is recommended (Section 4.3 – Channel Inspection and Maintenance Program).

4.4.2 Channel Repair Prioritization and Cost Estimates

Table 7 (*Channel Repair Prioritization and Cost Estimates*) was developed to aid in assessing the severity of the deterioration of the channel structures and to help prioritize the recommended repair alternatives.

The recommended repair alternatives are only developed to a conceptual level and the associated costs are gross, preliminary estimates. The remaining life pertains to the portion of the reach affected by the deficiency and not necessarily to the whole reach. The deficiency station limits may include box culvert segments, which are not affected by the deficiency but are accounted for in the percent of reach affected.

Table 7 – Channel Repair Prioritization and Cost Estimates

Reach No. [See Note 3]	Length of [Reach (M)]	Remaining Life (Years) [See Note 2]	Deficiency (Station Limits)	% of Reach Affected	Imminent Structural Concern	Alternative Corrective Measures	Add'l Life (Years)	Estimated Cost [See Note 1]
	445	5-10	Trapezoidal Channel Lining Deterioration (38+82 to 39+42)	15%	No	1) Redesign and replacement of the channel section	80	$0.12M
						2) No fix	0	$0
P 5	311	10-15 (Vertical Walled)	Vertical Temperature Expansion and Construction Cracks (40+07 to 42 +56)	80%	No	1) None, will be addressed with excessive wall deflection repair	N/A	N/A
			Excessive Wall Deflections (40+07 to 42+56)	80%	No	1) Redesign and replacement of the channel section	80	$0.91M
						2) Install vinyl sheet piling with concrete facing	50	$1.03M
						3) Construct reinforced concrete facing with concrete strut	50	$0.42M
						4) Construct reinforced concrete facing with piles	50	$1.00M
						5) Construct vertical walled bent	25	$0.11M
P 6	211	10-15	Vertical Temperature Expansion and Contraction Cracks (42+56 to 44+67)	85%	No	1) None, will be addressed with excessive wall deflection repair	N/A	N/A
			Excessive Wall Deflections (42+56 to 44+67)	85%	No	1) Redesign and replacement of the channel section	80	$0.66M
						2) Install vinyl sheet piling with concrete facing	50	$0.74M
						3) Construct reinforced concrete facing with concrete strut	50	$0.30M
						4) Construct reinforced concrete facing with piles	50	$0.72M
						5) Construct vertical walled bent	25	$0.08M

Table 7 – Channel Repair Prioritization and Cost Estimates

Reach No. [See Note 3]	Length of [Reach (M)]	Remaining Life (Years) [See Note 2]	Deficiency (Station Limits)	% of Reach Affected	Imminent Structural Concern	Alternative Corrective Measures	Add'l Life (Years)	Estimated Cost [See Note 1]
P 7	288	10-15	Vertical Temperature Expansion and Contraction Cracks (44+67 to 47+55)	95%	No	1) None, will be addressed with excessive wall deflection repair	N/A	N/A
			Excessive Wall Deflections (44+67 to 47+55)	95%	No	1) Total redesign and replacement of the channel section	80	$1.00M
						2) Install vinyl sheet piling with concrete facing	50	$1.13M
						3) Construct reinforced concrete facing with concrete strut	50	$0.46M
						4) Construct reinforced concrete facing with piles	50	$1.10M
						5) Construct vertical walled bent	25	$0.13M
P 8A	103	10-15	Vertical Temperature Expansion and Contraction Cracks (47+55 to 48+58)	70%	No	1) None, will be addressed with excessive wall deflection repair	N/A	N/A
			Excessive Wall Deflections (47+55 to 48+58)	70%	No	1) Redesign and replacement of the channel section	80	$0.26M
						2) Install vinyl sheet piling with concrete facing	50	$0.30M
						3) Construct reinforced concrete facing with concrete strut	50	$0.12M
						4) Construct reinforced concrete facing with piles	50	$0.29M
						5) Construct vertical walled bent	25	$0.03M

Table 7 – Channel Repair Prioritization and Cost Estimates

Reach No. [See Note 3]	Length of [Reach (M)]	Remaining Life (Years) [See Note 2]	Deficiency (Station Limits)	% of Reach Affected	Imminent Structural Concern	Alternative Corrective Measures	Add'l Life (Years)	Estimated Cost [See Note 1]
P 8A	252	10-15	Vertical Temperature Expansion and Contraction (48+58 to 51+10)	90%	No	1) None. Will be addressed with excessive wall deflection repair	N/A	N/A
			Excessive Wall Deflections (48+58 to 51+10)	90%	No	1) Redesign and replacement of the channel section	80	$0.83M
						2) Install vinyl sheet piling with concrete facing	50	$0.94M
						3) Construct reinforced concrete facing with concrete strut	50	$0.38M
						4) Construct reinforced concrete facing with piles	50	$0.92M
						5) Construct vertical walled bent	25	$0.10M
P 9	244	5-10	Vertical Temperature Expansion and Contraction Cracks (51+10 to 53+54)	95%	No	1) None, will be addressed with excessive wall deflection repair	N/A	N/A
			Excessive Wall Deflections (51+10 to 53+54)	95%	No	1) Redesign and replacement of the channel section	80	$0.85M
						2) Install vinyl sheet piling with concrete facing	50	$0.96M
						3) Construct reinforced concrete facing with concrete strut	50	$0.39M
						4) Construct reinforced concrete facing with piles	50	$0.94M
						5) Construct vertical walled bent	25	$0.11M

Table 7 – Channel Repair Prioritization and Cost Estimates

Reach No. [See Note 3]	Length of [Reach (M)]	Remaining Life (Years) [See Note 2]	Deficiency (Station Limits)	% of Reach Affected	Imminent Structural Concern	Alternative Corrective Measures	Add'l Life (Years)	Estimated Cost [See Note 1]
P 10	196	5-10	Vertical Temperature Expansion and Contraction Cracks (53+54 to 55+50)	90%	No	1) None, will be addressed with excessive wall deflection repair	N/A	N/A
			Excessive Wall Deflections (53+54 to 55+50)	90%	No	1) Redesign and replacement of the channel section	80	$0.65M
						2) Install vinyl sheet piling with concrete facing	50	$0.73M
						3) Construct reinforced concrete facing with concrete strut	50	$0.30M
						4) Construct reinforced concrete facing with piles	50	$0.71M
						5) Construct vertical walled bent	25	$0.08M
P 11A	182	5-10	Vertical Temperature Expansion and Contraction Cracks (55+50 to 57+32)	90%	No	1) None, will be addressed with excessive wall deflection repair	N/A	N/A
			Excessive Wall Deflections (55+50 to 57+32)	90%	No	1) Redesign and replacement of the channel section	80	$0.60M
						2) Install vinyl sheet piling with concrete facing	50	$0.68M
						3) Construct reinforced concrete facing with concrete strut	50	$0.27M
						4) Construct reinforced concrete facing with piles	50	$0.66M
						5) Construct vertical walled bent	25	$0.08M
			Wall Expansion Joint Deterioration (N/A)	100%	No	1) Implement maintenance program to annually inspect channel and fill any voids	N/A	See Note 1

Table 7 – Channel Repair Prioritization and Cost Estimates

Reach No. [See Note 3]	Length of [Reach (M)]	Remaining Life (Years) [See Note 2]	Deficiency (Station Limits)	% of Reach Affected	Imminent Structural Concern	Alternative Corrective Measures	Add'l Life (Years)	Estimated Cost [See Note 1]
P 11B	113	5-10	Vertical Temperature Expansion and Contraction Cracks (57+32 to 58+45)	85%	No	1) None, will be addressed with excessive wall deflection repair	N/A	N/A
			Excessive Wall Deflections (57+32 to 58+45)	85%	No	1) Total redesign and replacement of the channel section	80	$0.35M
						2) Install vinyl sheet piling with concrete facing	50	$0.40M
						3) Construct reinforced concrete facing with concrete strut	50	$0.16M
						4) Construct reinforced concrete facing with piles	50	$0.39M
						5) Construct vertical walled bent	25	$0.04M
P 12	184	5-10	Vertical Temperature Expansion and Contraction Cracks (58+45 to 60+29)	70%	No	1) None, will be addressed with excessive wall deflection repair	N/A	N/A
			Excessive Wall Deflections (58+45 to 60+29)	70%	No	1) Redesign and replacement of the channel section	80	$0.47M
						2) Install vinyl sheet piling with concrete facing	50	$0.53M
						3) Construct reinforced concrete facing with concrete strut	50	$0.22M
						4) Construct reinforced concrete facing with piles	50	$0.52M
						5) Construct vertical walled bent	25	$0.06M
P 13A	273	20-25	Wall Expansion Joint Deterioration (N/A)	100%	No	1) Implement maintenance program to annually inspect channel and any fill any voids	N/A	See Note 1

Table 7 – Channel Repair Prioritization and Cost Estimates

Reach No. [See Note 3]	Length of [Reach (M)]	Remaining Life (Years) [See Note 2]	Deficiency (Station Limits)	% of Reach Affected	Imminent Structural Concern	Alternative Corrective Measures	Add'l Life (Years)	Estimated Cost [See Note 1]
P 13B	53	15-20	None (63+02 to 63+55)	N/A	No	1) N/A	N/A	N/A
P 14	794	20-25	Exposed Reinforcement Due to Lack of Concrete Cover (70+35 to 70+75)	5%	No	1) Remove unsound concrete, clean and patch concrete	5	$3910
P 15A	125	5-10	Vertical Temperature Expansion and Contraction Cracks (71+49 to 72+74)	95%	No	1) None, will be addressed with excessive wall deflection repair	N/A	N/A
			Excessive Wall Deflections (71+49 to 72+74)	95%	No	1) Redesign and replacement of the channel section	80	$0.44M
						2) Install vinyl sheet piling with concrete facing	50	$0.49M
						3) Construct reinforced concrete facing with concrete strut	50	$0.20M
						4) Construct reinforced concrete facing with piles	50	$0.48M
						5) Construct vertical walled bent	20	$0.05M
P 15B	286	0-5	Vertical Temperature Expansion and Contraction Cracks (72+74 to 75+60)	100%	No	1) None, will be addressed with excessive wall deflection repair	N/A	N/A
			Excessive Wall Deflections (72+74 to 75+60)	100%	No	1) Redesign and replacement of the channel section	80	$2.16M
						2) Install vinyl sheet piling with concrete facing	50	$1.18M
						3) Construct reinforced concrete facing with concrete strut	50	$0.49M
						4) Construct reinforced concrete facing with piles	50	$1.13M
						5) Construct vertical walled bent	20	$0.13M

Table 7 – Channel Repair Prioritization and Cost Estimates

Reach No. [See Note 3]	Length of [Reach (M)]	Remaining Life (Years) [See Note 2]	Deficiency (Station Limits)	% of Reach Affected	Imminent Structural Concern	Alternative Corrective Measures	Add'l Life (Years)	Estimated Cost [See Note 1]
P 16	376	0-5	Vertical Temperature Expansion and Contraction Cracks (78+42 to 79+10)	85%	No	1) None, will be addressed with excessive wall deflection repair	N/A	N/A
			Exposed Reinforcement Due to Lack of Concrete Cover (75+60 to 75+64) (77+13 to 77+15)	5%	No	1) None, will be addressed with excessive wall deflection repair	N/A	N/A
			Excessive Wall Deflections (75+60 to 79+10)	85%	Yes	1) Redesign and replacement of the channel section	80	$1.17M
						2) Install vinyl sheet piling with concrete facing	50	$1.32M
						3) Construct reinforced concrete facing with concrete strut	50	$0.53M
						4) Construct reinforced concrete facing with piles	50	$1.29M
						5) Construct vertical walled bent	20	$0.15M
P 20	120	10-15	None (90+40 to 91+60)	arch culvert only	No	1) None, overall condition of culvert is good with 10-15 years of life remaining	N/A	N/A
P 23	380	35-40	Exposed Reinforcement Due to Lack of Concrete Cover (106+30)	1%	No	1) Remove unsound concrete, clean, and patch concrete	5	$1000
H 1A	91	15-20	None (00+00 to 00+91)	N/A	No	1) None, overall, condition of channel is good with 15-20 years of life remaining	N/A	N/A

Table 7 – Channel Repair Prioritization and Cost Estimates

Reach No. [See Note 3]	Length of [Reach (M)]	Remaining Life (Years) [See Note 2]	Deficiency (Station Limits)	% of Reach Affected	Imminent Structural Concern	Alternative Corrective Measures	Add'l Life (Years)	Estimated Cost [See Note 1]
H 1B	29	15-20	Exposed Reinforcement Due to Lack of Concrete Cover (02+08 to 02+36)	1%	No	1) Remove unsound concrete, clean, and patch concrete	5	$1000
			Wall Expansion Joint Deterioration (N/A)	100%	No	1) Implement maintenance program to annually inspect channel and fill any voids.	N/A	See Note 1
H 2A	133	5-10	Wall Expansion Joint Deterioration (N/A)	100%	No	1) None, will be addressed with Trapezoidal Channel Lining Deterioration repair	N/A	See Note 1
			Trapezoidal Channel Lining Deterioration (04+50 to 05+19)	80%	No	1) Total replacement of the channel section	80	$0.20M
						2) No fix	0	$0
H 2B	715	5-10	Exposed Reinforcement Due to Lack of Concrete Cover (07+12 to 07+15)	5%	No	1) None, will be addressed with Trapezoidal Channel Lining Deterioration repair	N/A	N/A
			Trapezoidal Channel Lining Deterioration (05+19 to 07+ 15)	90%	No	1) Redesign and replacement of the channel section	80	$0.12M
						2) No fix	0	$0
H 3A	225	5-10	Exposed Reinforcement Due to Lack of Concrete Cover (08+96 to 09+00)	5%	No	1) None, will be addressed with Trapezoidal Channel Lining Deterioration repair	N/A	N/A
			Trapezoidal Channel Lining Deterioration (07+37 to 09+62)	90%	No	1) Redesign and replacement of the channel section	80	$0.38M
						2) No fix	0	$0
H 3B	134	5-10	Wall Expansion Joint Deterioration (N/A)	100%	No	1) Implement yearly maintenance program to inspect channel and any fill any voids	N/A	See Note 1
			Trapezoidal Channel Lining Deterioration (09+62 to 10+96)	90%	No	1) Redesign and replacement of the channel section	80	$0.23M
						2) No fix	0	$0

Table 7 – Channel Repair Prioritization and Cost Estimates

Reach No. [See Note 3]	Length of [Reach (M)]	Remaining Life (Years) [See Note 2]	Deficiency (Station Limits)	% of Reach Affected	Imminent Structural Concern	Alternative Corrective Measures	Add'l Life (Years)	Estimated Cost [See Note 1]
H 4	292	5-10	Exposed Reinforcement Due to Lack of Concrete Cover (11+40 to 11+44)	5%	No	1) None, will be addressed with Trapezoidal Channel Lining Deterioration repair	N/A	N/A
			Trapezoidal Channel Lining Deterioration (10+96 to 13+88)	85%	No	1) Redesign and replacement of the channel section	80	$0.46M
						2) No fix	0	$0
H 5A	112	5-10	Wall Expansion Joint Deterioration (N/A)	100%	No	1) Implement maintenance program to annually inspect channel and fill any voids	N/A	See Note 1
			Exposed Reinforcement Due to Lack of Concrete Cover (14+46 to 14+56)	1%	No	1) Remove unsound concrete, clean, and patch concrete	5	$1000
			Trapezoidal Channel Lining Deterioration (13+88 to 15+00)	75%	No	1) Redesign and replacement of the channel section	80	$0.16M
						2) No fix	0	$0
H 5B	246	0-5	Vertical Temperature Expansion and Contraction Cracks	90%	No	1) None, will be addressed with longitudinal cracking of the invert repair	N/A	N/A
			Exposed Reinforcement Due to Lack of Concrete Cover (15+37 to 17+39)	45%	No	1) None, will be addressed with longitudinal cracking of the invert repair	N/A	N/A
			Excessive Wall Deflections (15+24 to 17+46)	90%	Yes	1) None, will be addressed with longitudinal cracking of the invert repair	N/A	N/A
			Longitudinal Cracking of the Invert (15+24 to 17+46)	90%	Yes	1) Redesign and replacement of the channel section	80	$1.67M
						2) Install vinyl sheet piling with concrete facing	50	$0.41M
						3) Construct vertical walled bent	20	$0.10 M

Table 7 – Channel Repair Prioritization and Cost Estimates

Reach No. [See Note 3]	Length of [Reach (M)]	Remaining Life (Years) [See Note 2]	Deficiency (Station Limits)	% of Reach Affected	Imminent Structural Concern	Alternative Corrective Measures	Add'l Life (Years)	Estimated Cost [See Note 1]
PD 1	240	5-10	Trapezoidal Channel Lining Deterioration (00+75 to 02+40)	70%	No	1) Redesign and replacement of the channel section	80	$0.31M
						2) No fix	0	$0
PD 2	1152	5-10	Trapezoidal Channel Lining Deterioration (02+40 to 13+92)	100%	No	1) Redesign and replacement of the channel section		$2.40M
						2) No fix	0	$0
			Wall Expansion Joint Deterioration (N/A)	100%	No	1) Implement annually maintenance program to inspect channel and fill any voids	N/A	See Note 1
PD 3	430	15-20 (Vertical Walled) (15-20) (Concrete Lining)	Vertical Temperature Expansion and Contraction Cracks (16+00 to 18+22)	40%	No	1) None, implement annually maintenance program to monitor rate of corrosion	N/A	N/A
			Wall Expansion Joint Deterioration (N/A)	100%	No	1) Implement annually maintenance program to inspect channel and fill any voids	N/A	See Note 1
			Trapezoidal Channel Lining Deterioration (13+92 to 16+00)	40%	No	1) Redesign and replacement of the channel section	80	$0.32M
						2) No fix	0	$0
PD 4	338	5-10 (Concrete Lining) 15-20 (Vertical Walled)	Trapezoidal Channel Lining Deterioration (18+82 to 21+60)	80%	No	1) Redesign and replacement of the channel section	80	$0.57M
						2) No fix	0	$0

Notes:

1) The estimated cost of $50,000 per year for implementing an annual maintenance program applies to inspection and maintenance of the entire alignment. Repair construction costs that are determined to be necessary under the maintenance program are not included in the estimated maintenance cost.
2) There were no deficiencies on any of the box culverts along the alignment, except for a little localized abrasion of the invert. The estimated remaining life of the box culvert portions of each reach is 20 to 25 years.
3) See Table 1 for Reach Number Descriptions.

Appendix A

Site Investigation Summary Reports

SUMMARY REPORT OF SITE INVESTIGATION

General Information:

Creek Name: Permanente Creek	*SCVWD Reach No.*: P 4
Location: Charleston Rd. to Hwy 101	*Channel Type*: Concrete Trapezoidal
Date of Original Construction: 1960	*Date of Inspection*: 7/26/99

General Dimensions:

Channel Height: 11ft	*Convention*: Looking Up-Station
Channel Width at Top: Mostly 38ft	*Channel Slope Left*: 1:1
Channel Width at Bottom: 16ft	*Channel Slope Right*: 1:1

General Condition of Reach:

CONCERNS	*GENERAL REMARKS*
Concrete Cracks	Moderate horizontal and vertical temperature cracks were found along the entire reach. See Picture #1.
Surface Defects	No notable surface defects found.
Reinforcement	No exposed reinforcement was found.
Structural Deformation	None detected.
Soil Stability	N/A
Other	Much sediment and vegetation was found within the channel. See Picture #2.

General Condition of Channel for Future Structural Repair/Modification:

Spatial Limitations for Any Repair/Modification	Fence found on left side of channel (looking up-station). See Picture #3.

Summary and Conclusions:

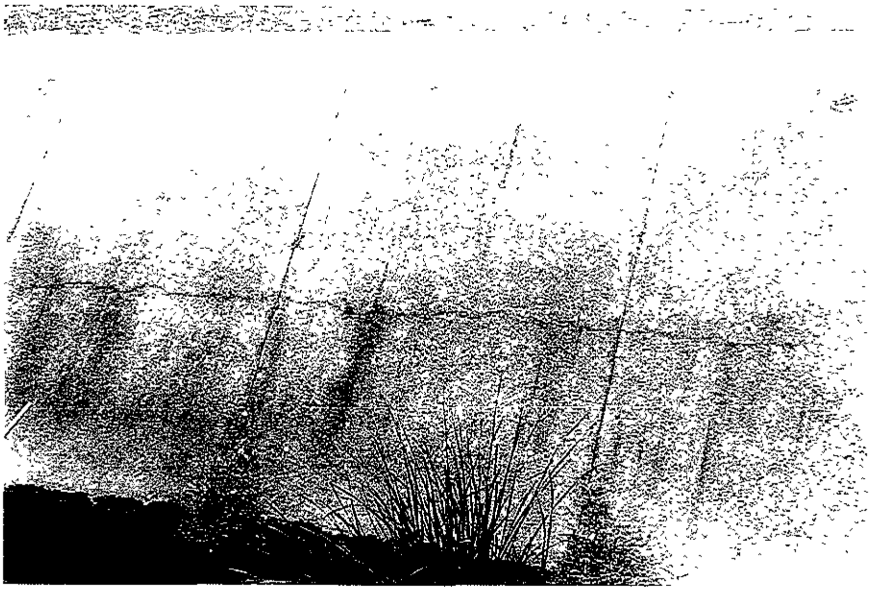
Summary of Investigation:

The moderate horizontal and vertical cracks found along the entire reach are due to unaccounted for loads resisted by the channel lining. These cracks incurred by the channel will reduce its structural life expectancy.

Conclusions and Recommendations:

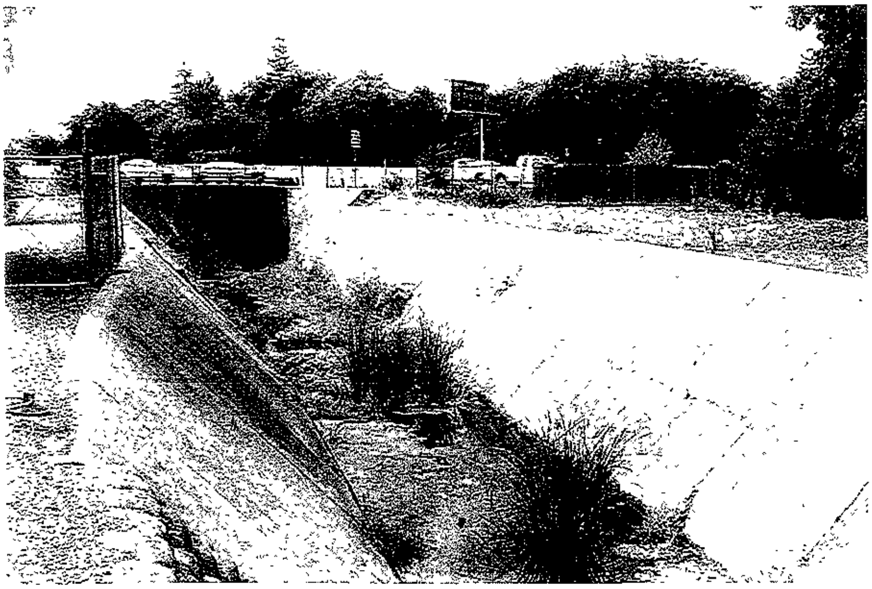
Since the channel lining has incurred the cracking specified above, we recommend the replacement of the trapezoidal channel lining for reach P 4 within the next 10 years.

Structural Life Expectancy: 5-10 yrs



P 4 Picture #1

P 4 Picture #2



P 4 Picture #3

SUMMARY REPORT OF SITE INVESTIGATION

General Information:

Creek Name: Permanente Creek	*SCVWD Reach No.*: P5
Location: Hwy 101 to Old Middlefield Way	*Channel Type*: Mostly Concrete U-Frame
Date of Original Construction: 1967	*Date of Inspection*: 7/26/99

General Dimensions:

Channel Height: Mostly 11ft	*Convention*: Looking Up-Station
Channel Width at Top: 12ft	*Channel Slope Left*: N/A
Channel Width at Bottom: 12ft	*Channel Slope Right*: N/A

General Condition of Reach:

CONCERNS	*GENERAL REMARKS*
Concrete Cracks	Moderate vertical temperature cracks were found along the entire reach. See Picture #1 as an example.
Surface Defects	Minor abrasion at the base of the walls throughout entire the reach.
Reinforcement	No exposed reinforcement found.
Structural Deformation	Severe to moderate wall deflections were found along the entire reach (for U-Frame only). Max. deflection found to be 2.6 times yield displacement. See Picture #2 as an example.
Soil Stability	N/A
Other	Much sediment was found in the box culvert.

General Condition of Channel for Future Structural Repair/Modification:

Spatial Limitations for Any Repair/Modification	Mostly consists of a chain link fence and vegetation above the right channel wall (when looking up-station). See Picture #3.

Summary and Conclusions:

Summary of Investigation:

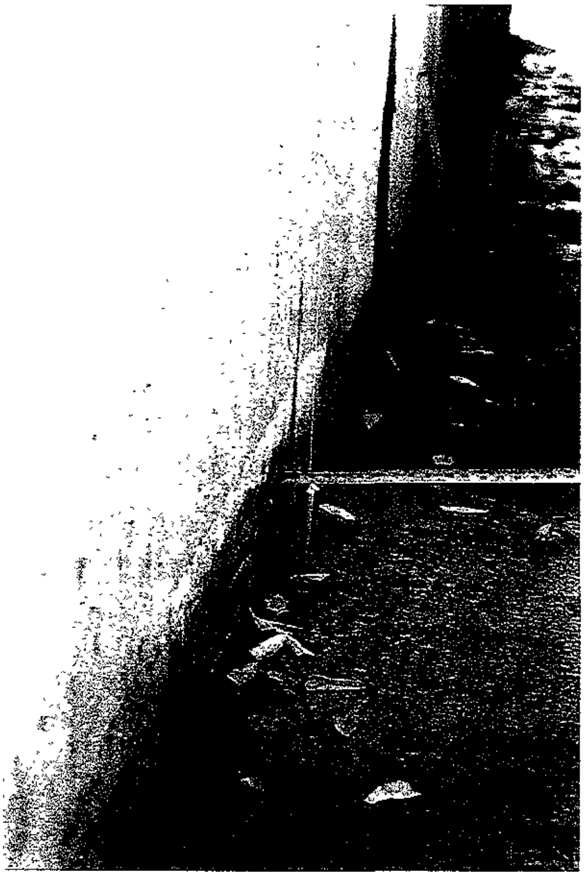
Minor abrasion can be seen on the walls. Such surface defects are expected to occur during the service life of the channel. However, excessive wall deflections were found along the entire reach (for U-Frame only). These excessive wall deflections are most likely due to a wall design load which is less than the actual load the walls resist.

Conclusions and Recommendations:

Since the vertical walls of the reach have sustained moderate to severe wall deflections, we recommend rehabilitation of the existing U-Frame channel for reach P5 within the next 15 years.

Structural Life Expectancy: 10-15 yrs (U-Frame only) 20-25 yrs (Box Culvert)

P 5 Picture #1



P 5 Picture #2

P 5 Picture #3

SUMMARY REPORT OF SITE INVESTIGATION

General Information:

Creek Name: Permanente Creek	*SCVWD Reach No.*: P 6
Location: Old Middlefield Way to Rock Street	*Channel Type*: Concrete U-Frame
Date of Original Construction: 1967	*Date of Inspection*: 7/26/99

General Dimensions:

Channel Height: Mostly 9ft	*Convention*: Looking Up-Station
Channel Width at Top: 12ft	*Channel Slope Left*: N/A
Channel Width at Bottom: 12ft	*Channel Slope Right*: N/A

General Condition of Reach:

CONCERNS	*GENERAL REMARKS*
Concrete Cracks	Moderate vertical temperature cracks were found along the entire reach. See Picture #1 as an example.
Surface Defects	Minor abrasion at the base of the walls throughout entire the reach. Minor efflorescence on the walls for 30% of the reach.
Reinforcement	No exposed reinforcement found.
Structural Deformation	Severe to moderate wall deflections were found along the entire reach. Max. deflection found to be 2.6 times yield displacement. See Picture #2 as an example.
Soil Stability	N/A
Other	Nearly all of the weep holes are clogged with vegetation and/or soil. See Picture #3. Water is draining from expansion joints rather than weep holes.

General Condition of Channel for Future Structural Repair/Modification:

Spatial Limitations for Any Repair/Modification	Mostly consists of a chain link fence and vegetation above the right channel wall (when looking up-station).

Summary and Conclusions:

Summary of Investigation:

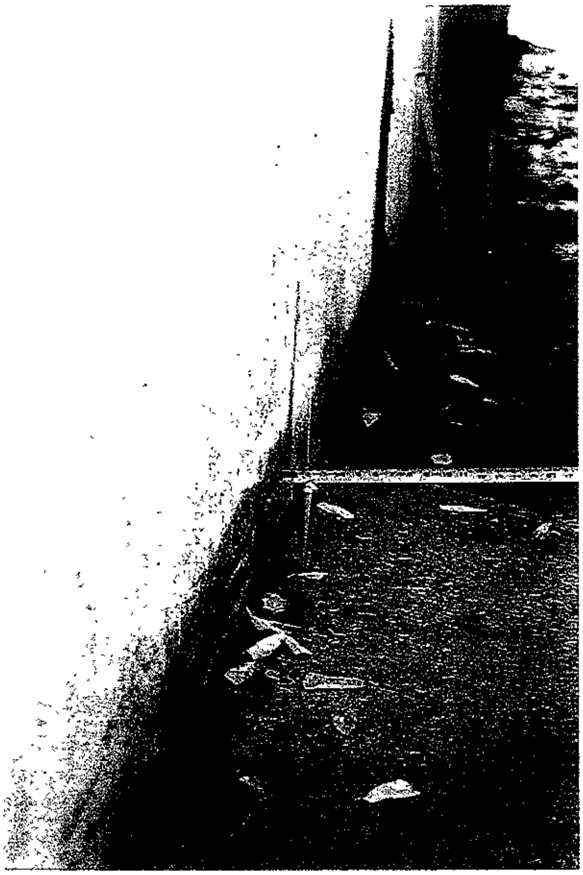
Minor efflorescence and abrasion can be seen on the walls. Such surface defects are expected to occur during the service life of the channel. However, excessive wall deflections were found along the entire reach. These excessive wall deflections are most likely due to a wall design load which is less than the actual load the walls resist.

Conclusions and Recommendations:

Since the vertical walls of the reach have sustained moderate to severe wall deflections, we recommend rehabilitation of the existing U-Frame channel for reach P6 within the next 15 years.

Structural Life Expectancy: 10-15 yrs (U-Frame only) 20-25 yrs (Box Culvert)

P 6 Picture #1



P 6 Picture #2

P 6 Picture #3

SUMMARY REPORT OF SITE INVESTIGATION

General Information:

Creek Name: Permanente Creek	*SCVWD Reach No.*: P 7
Location: Rock Street to W. Middlefield Road	*Channel Type*: Concrete U-Frame
Date of Original Construction: 1967	*Date of Inspection*: 7/26/99

General Dimensions:

Channel Height: Mostly 9ft	*Convention*: Looking Up-Station
Channel Width at Top: 12ft	*Channel Slope Left*: N/A
Channel Width at Bottom: 12ft	*Channel Slope Right*: N/A

General Condition of Reach:

CONCERNS	*GENERAL REMARKS*
Concrete Cracks	Moderate vertical temperature cracks were found along the entire reach. See Picture #1 as an example.
Surface Defects	Minor abrasion and efflorescence occurs sporadically on the walls of the channel throughout the reach.
Reinforcement	No exposed reinforcement found.
Structural Deformation	Severe to moderate wall deflections were found along the entire reach. Max. deflection found to be 2.6 times yield displacement. See Picture #2 as an example.
Soil Stability	N/A
Other	Approximately half of the weep holes are clogged with vegetation and/or soil. See Picture #3.

General Condition of Channel for Future Structural Repair/Modification:

Spatial Limitations for Any Repair/Modification	Chain link fence above both channel walls throughout the reach. Also vegetation occurring sporadically on either side of the channel. See Picture #4.

Summary and Conclusions:

Summary of Investigation:

Minor efflorescence and abrasion can be seen on the walls. Such surface defects are expected to occur during the service life of the channel. However, excessive wall deflections were found along the entire reach. These excessive wall deflections are most likely due to a wall design load which is less than the actual load the walls resist.

Conclusions and Recommendations:

Since the vertical walls of the reach have sustained moderate to severe wall deflections, we recommend rehabilitation of the existing U-Frame channel for reach P7 within the next 15 years.

Structural Life Expectancy: 10-15 yrs (U-Frame only) 20-25 yrs (Box Culvert)

P 7 Picture #1

P 7 Picture #2

P 7 Picture #3

P 7 Picture #4

SUMMARY REPORT OF SITE INVESTIGATION

General Information:

Creek Name: Permanente Creek	*SCVWD Reach No.*: P 8A
Location: W. Middlefield Rd. to San Ramone Ave.	*Channel Type*: Concrete U-Frame
Date of Original Construction: 1967	*Date of Inspection*: 7/26/99

General Dimensions:

Channel Height: Mostly 9ft	*Convention*: Looking Up-Station
Channel Width at Top: 12ft	*Channel Slope Left*: N/A
Channel Width at Bottom: 12ft	*Channel Slope Right*: N/A

General Condition of Reach:

CONCERNS	*GENERAL REMARKS*
Concrete Cracks	Moderate vertical temperature cracks were found along the entire reach. See Picture #1 as an example.
Surface Defects	Minor delamination and abrasion on the invert slab of one joint. Minor abrasion and efflorescence occurs sporadically on the walls of the channel throughout the reach.
Reinforcement	No exposed reinforcement found.
Structural Deformation	Severe to moderate wall deflections were found along the entire reach. Max. deflection found to be 2.6 times yield displacement. See Picture #2 as an example.
Soil Stability	N/A
Other	N/A

General Condition of Channel for Future Structural Repair/Modification:

Spatial Limitations for Any Repair/Modification	Chain link fence above both channel walls throughout the reach and vegetation found sporadically on either side of the channel. See Picture #3.

Summary and Conclusions:

Summary of Investigation:

The condition of the channel, as it pertains surface defects is good. However, excessive wall deflections were found along the entire reach. These excessive wall deflections are most likely due to a wall design load which is less than the actual load the walls resist.

Conclusions and Recommendations:

Since the vertical walls of the reach have sustained moderate to severe wall deflections, we recommend rehabilitation of the existing U-Frame channel for reach P8A within the next 15 years.

Structural Life Expectancy: 10-15 yrs (U-Frame only) 20-25 yrs (Box Culvert)

P 8A Picture #1

P 8A Picture #2

P 8A Picture #3

SUMMARY REPORT OF SITE INVESTIGATION

General Information:

Creek Name: Permanente Creek	*SCVWD Reach No.*: P 8B
Location: San Ramone Ave. to San Luis Ave.	*Channel Type*: Concrete U-Frame
Date of Original Construction: 1967	*Date of Inspection*: 7/26/99

General Dimensions:

Channel Height: Mostly 9ft	*Convention*: Looking Up-Station
Channel Width at Top: 12ft	*Channel Slope Left*: N/A
Channel Width at Bottom: 12ft	*Channel Slope Right*: N/A

General Condition of Reach:

CONCERNS	*GENERAL REMARKS*
Concrete Cracks	Moderate vertical temperature cracks were found along the entire reach. See Picture #1 as an example.
Surface Defects	Minor abrasion and efflorescence occurs sporadically on the walls of the channel throughout the reach.
Reinforcement	No exposed reinforcement found.
Structural Deformation	Severe to moderate wall deflections were found along the entire reach. Max. deflection found to be 5.2 times yield displacement. See Picture #2 as an example.
Soil Stability	N/A
Other	N/A

General Condition of Channel for Future Structural Repair/Modification:

Spatial Limitations for Any Repair/Modification	Chain link fence above both channel walls throughout the reach and vegetation found sporadically on either side of the channel. See Picture #3.

Summary and Conclusions:

Summary of Investigation:

The condition of the channel, as it pertains to surface defects is good. Minor abrasion and efflorescence can be found on the channel walls. Such surface defects are expected to occur during the service life of the channel. However, excessive wall deflections were found along the entire reach. These excessive wall deflections are most likely due to a wall design load which is less than the actual load the walls resist.

Conclusions and Recommendations:

Since the vertical walls of the reach have sustained moderate to severe wall deflections, we recommend rehabilitation of the existing U-Frame channel for reach P8B within the next 10 years.

Structural Life Expectancy: 5-10 yrs (U-Frame only) 20-25 yrs (Box Culvert)

P 8B Picture #1

P 8B Picture #2

P 8B Picture #3

SUMMARY REPORT OF SITE INVESTIGATION

General Information:

Creek Name: Permanente Creek	*SCVWD Reach No.*: P 9
Location: San Luis Ave. to Montecito Ave.	*Channel Type*: Concrete U-Frame
Date of Original Construction: 1967	*Date of Inspection*: 7/26/99

General Dimensions:

Channel Height: Mostly 9ft	*Convention*: Looking Up-Station
Channel Width at Top: 12ft	*Channel Slope Left*: N/A
Channel Width at Bottom: 12ft	*Channel Slope Right*: N/A

General Condition of Reach:

CONCERNS	*GENERAL REMARKS*
Concrete Cracks	Moderate vertical temperature cracks were found along the entire reach. See Picture #1 as an example.
Surface Defects	Minor abrasion and efflorescence occurs sporadically on the walls of the channel throughout the entire reach. Minor pop-outs occur on the channel walls for 60% of the reach.
Reinforcement	No exposed reinforcement found.
Structural Deformation	Severe to moderate wall deflections were found along the entire reach. Max. deflection found to be 5.2 times yield displacement. See Picture #2 as an example.
Soil Stability	N/A
Other	N/A

General Condition of Channel for Future Structural Repair/Modification:

Spatial Limitations for Any Repair/Modification	Chain link fence above both channel walls throughout the reach and vegetation found sporadically on either side of the channel. See Picture #3.

Summary and Conclusions:

Summary of Investigation:
Minor efflorescence, abrasion and pop-outs can be seen on the channel walls. Such surface defects are expected to occur during the service life of the channel. However, excessive wall deflections were found along the entire reach. These excessive wall deflections are most likely due to a wall design load which is less than the actual load the walls resist.

Conclusions and Recommendations:
Since the vertical walls of the reach have sustained moderate to severe wall deflections, we recommend rehabilitation of the existing U-Frame channel for reach P9 within the next 10 years.

Structural Life Expectancy: 5-10 yrs (U-Frame only) 20-25 yrs (Box Culvert)

P 9 Picture #1

P 9 Picture #2

P 9 Picture #3

SUMMARY REPORT OF SITE INVESTIGATION

General Information:

Creek Name: Permanente Creek	*SCVWD Reach No.*: P 10
Location: Montecito Ave. to Hackett Ave.	*Channel Type*: Concrete U-Frame
Date of Original Construction: 1967	*Date of Inspection*: 7/26/99

General Dimensions:

Channel Height: 9ft	*Convention*: Looking Up-Station
Channel Width at Top: 12ft	*Channel Slope Left*: N/A
Channel Width at Bottom: 12ft	*Channel Slope Right*: N/A

General Condition of Reach:

CONCERNS	*GENERAL REMARKS*
Concrete Cracks	Moderate vertical temperature cracks were found along the entire reach. See Picture #1 as an example.
Surface Defects	Minor abrasion and efflorescence occurs sporadically on the walls of the channel throughout the entire reach.
Reinforcement	No exposed reinforcement found.
Structural Deformation	Severe to moderate wall deflections were found along the entire reach. Max. deflection found to be 5.2 times yield displacement. See Picture #2 as an example.
Soil Stability	N/A
Other	N/A

General Condition of Channel for Future Structural Repair/Modification:

Spatial Limitations for Any Repair/Modification	Chain link fence above both channel walls throughout the reach and vegetation found sporadically on either side of the channel. See Picture #3.

Summary and Conclusions:

Summary of Investigation:

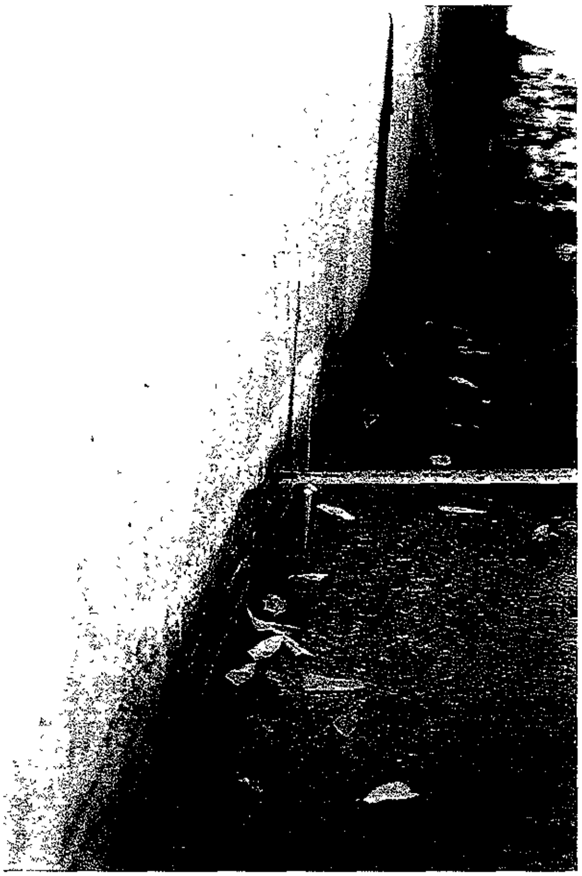
Minor abrasion and efflorescence can be seen on the channel walls. Such surface defects are expected to occur during the service life of the channel. However, excessive wall deflections were found along the entire reach. These excessive wall deflections are most likely due to a wall design load which is less than the actual load the walls resist.

Conclusions and Recommendations:

Since the vertical walls of the reach have sustained moderate to severe wall deflections, we recommend rehabilitation of the existing U-Frame channel for reach P10 within the next 10 years.

Structural Life Expectancy: 5-10 yrs (U-Frame only) 20-25 years (Box Culvert)

P 10 Picture #1



P 10 Picture #2

P 10 Picture #3

SUMMARY REPORT OF SITE INVESTIGATION

General Information:

Creek Name: Permanente Creek	*SCVWD Reach No.*: P 11A
Location: Hackett Ave. to Hetch-Hetchy	*Channel Type*: Concrete U-Frame
Date of Original Construction: 1967	*Date of Inspection*: 7/27/99

General Dimensions:

Channel Height: Ranges from 9ft to 11ft	*Convention*: Looking Up-Station
Channel Width at Top: 12ft	*Channel Slope Left*: N/A
Channel Width at Bottom: 12ft	*Channel Slope Right*: N/A

General Condition of Reach:

CONCERNS	*GENERAL REMARKS*
Concrete Cracks	Moderate vertical temperature cracks were found along the entire reach. See Picture #1 as an example. Moderate cracks on channel walls at three separate expansion joints along the reach. See Picture #2.
Surface Defects	Minor abrasion and efflorescence occurs sporadically on the walls of the channel throughout the reach.
Reinforcement	Moderate exposed reinforcement (specifically, dowels) at one expansion joint due to deteriorating or missing joint filler.
Structural Deformation	Severe to moderate wall deflections were found along the entire reach. Max. deflection found to be 5.2 times yield displacement. See Picture #3 as an example.
Soil Stability	N/A
Other	N/A

General Condition of Channel for Future Structural Repair/Modification:

Spatial Limitations for Any Repair/Modification	Chain link fence above both channel walls throughout the reach. Houses are offset approximately 10ft from channel walls. Vegetation is found on either side of channel. See Picture #4.

Summary and Conclusions:

Summary of Investigation:

Moderate cracks on the channel walls at three separate expansion joints have been found. These cracks are probably due to pounding from adjacent channel segments during a seismic event. Moderate exposed reinforcement (specifically, dowels) at one expansion joint has also been noted. They are exposed because the expansion joint filler material is missing and/or deteriorated. However, excessive wall deflections were found along the entire reach. These excessive wall deflections are most likely due to a wall design load which is less than the actual load the walls resist.

Conclusions and Recommendations:

Since the vertical walls of the reach have sustained moderate to severe wall deflections, we recommend rehabilitation of the existing U-Frame channel for reach P11A within the next 10 years.

Structural Life Expectancy: 5-10 yrs (U-Frame only) 20-25 yrs (Box Culvert)

P 11A Picture #1

P 11A Picture #2

P 11A Picture #3

P 11A Picture #4

SUMMARY REPORT OF SITE INVESTIGATION

General Information:

Creek Name: Permanente Creek	*SCVWD Reach No.*: P 11B
Location: Hetch-Hetchy to SPRR	*Channel Type*: Concrete U-Frame
Date of Original Construction: 1967	*Date of Inspection*: 7/27/99

General Dimensions:

Channel Height: Ranges from 8ft to 11ft	*Convention*: Looking Up-Station
Channel Width at Top: 12ft	*Channel Slope Left*: N/A
Channel Width at Bottom: 12ft	*Channel Slope Right*: N/A

General Condition of Reach:

CONCERNS	*GENERAL REMARKS*
Concrete Cracks	Moderate vertical temperature cracks were found along the entire reach. See Picture #1 as an example. Two moderate cracks were found in the invert slab at two separate locations. See Picture #2.
Surface Defects	Minor abrasion and efflorescence was found on 15% of the reach.
Reinforcement	No exposed reinforcement found.
Structural Deformation	Severe to moderate wall deflections were found along the entire reach. Max. deflection found to be 5.2 times yield displacement. See Picture #3 as an example.
Soil Stability	N/A
Other	N/A

General Condition of Channel for Future Structural Repair/Modification:

Spatial Limitations for Any Repair/Modification	Chain link fence above both channel walls along 15% of reach. Utility pipes cross over channel (just south of Central Expressway and adjacent to SPRR tracks). See Picture #4.

Summary and Conclusions:

Summary of Investigation:

Two moderate cracks in the invert slab were found at two separate locations. The exact cause(s) of these cracks is unknown at this time. These cracks are not considered to be of significant structural concern. Minor abrasion and efflorescence was found in the channel. These surface defects are expected to occur during the service life of the channel. However, excessive wall deflections were found along the entire reach. These excessive wall deflections are most likely due to a wall design load which is less than the actual load the walls resist.

Conclusions and Recommendations:

Since the vertical walls of the reach have sustained moderate to severe wall deflections, we recommend rehabilitation of the existing U-Frame channel for reach P11B within the next 10 years.

Structural Life Expectancy: 5-10 yrs (U-Frame only) 20-25 yrs (Box Culvert)

P 11B Picture #1

P 11B Picture #2

P 11B Picture #3

P 11B Picture #4

SUMMARY REPORT OF SITE INVESTIGATION

General Information:

Creek Name: Permanente Creek	*SCVWD Reach No.*: P 12
Location: SPRR to Villa St.	*Channel Type*: Concrete U-Frame
Date of Original Construction: 1967	*Date of Inspection*: 7/27/99

General Dimensions:

Channel Height: Ranges from 10ft to 11.75ft	*Convention*: Looking Up-Station
Channel Width at Top: Ranges from 9.5ft to 10.5ft	*Channel Slope Left*: N/A
Channel Width at Bottom: Same as above.	*Channel Slope Right*: N/A

General Condition of Reach:

CONCERNS	*GENERAL REMARKS*
Concrete Cracks	Moderate vertical temperature cracks were found along the entire reach. See Picture #1 as an example.
Surface Defects	No notable surface defects found.
Reinforcement	No exposed reinforcement found.
Structural Deformation	Severe to moderate wall deflections were found along the entire reach. Max. deflection found to be 3.9 times yield displacement. See Picture #2 as an example.
Soil Stability	N/A
Other	N/A

General Condition of Channel for Future Structural Repair/Modification:

Spatial Limitations for Any Repair/Modification	Chain link fence above both channel walls for nearly all of reach. Utility pipes and railway cross channel (just south of Central Expressway). Vegetation exists above and/or within the channel for the majority of the reach. See Picture #3.

Summary and Conclusions:

Summary of Investigation:

The overall condition of the channel, as it pertains to surface defects is good. However, excessive wall deflections were found along the entire reach. These excessive wall deflections are most likely due to a wall design load which is less than the actual load the channel walls resist.

Conclusions and Recommendations:

Since the vertical walls of the reach have sustained moderate to severe wall deflections, we recommend rehabilitation of the existing U-Frame channel for reach P12 within the next 10 years.

Structural Life Expectancy: 5-10 yrs

P 12 Picture #1

P 12 Picture #2

P 12 Picture #3

SUMMARY REPORT OF SITE INVESTIGATION

General Information:

Creek Name: Permanente Creek	*SCVWD Reach No.*: P 13A
Location: U/S to D/S Villa St. culvert	*Channel Type*: Concrete Box Culvert
Date of Original Construction: 1963-1964	*Date of Inspection*: 7/27/99

General Dimensions:

Channel Height: Ranges from 8.33ft to 10ft	*Convention*: Looking Up-Station
Channel Width at Top: 10ft	*Channel Slope Left*: N/A
Channel Width at Bottom: 10ft	*Channel Slope Right*: N/A

General Condition of Reach:

CONCERNS	*GENERAL REMARKS*
Concrete Cracks	Two moderate cracks were found at two separate joint locations. See Picture #1.
Surface Defects	Minor efflorescence was found on 30% of reach. Moderate abrasion was found on 10% of reach. See Picture #2.
Reinforcement	Two moderate exposed reinforcement (specifically, dowels) found at two separate joint locations.
Structural Deformation	None detected.
Soil Stability	N/A
Other	N/A

General Condition of Channel for Future Structural Repair/Modification:

Spatial Limitations for Any Repair/Modification	N/A

Summary and Conclusions:

Summary of Investigation:

Two moderate cracks were found at two separate joint locations. These cracks are probably due to pounding from adjacent box segments during a seismic event. This action is most likely responsible for the moderate exposed reinforcement at the same joint locations. Minor efflorescence was found on the top slab and the walls while moderate abrasion was found on the invert slab. However, these surface defects are expected to occur during the service life of the channel.

Conclusions and Recommendations:

Although reach P13A has incurred some damage, the damage has been deemed insignificant as it relates to its overall structural integrity. Thus, the overall condition is of the reach is good.

Structural Life Expectancy: 20-25 yrs

P 13A Picture #1

P 13A Picture #2

SUMMARY REPORT OF SITE INVESTIGATION

General Information:

Creek Name: Permanente Creek	*SCVWD Reach No.*: P 13B
Location: U/S Villa St. to Calif./El Camino culverts	*Channel Type*: Concrete Trapezoidal
Date of Original Construction: 1958	*Date of Inspection*: 7/27/99

General Dimensions:

Channel Height: 8ft	*Convention*: Looking Up-Station
Channel Width at Top: 24ft	*Channel Slope Left*: 1:1
Channel Width at Bottom: 8ft	*Channel Slope Right*: 1:1

General Condition of Reach:

CONCERNS	*GENERAL REMARKS*
Concrete Cracks	Concrete appears to be in good condition.
Surface Defects	No notable surface defects found.
Reinforcement	No exposed reinforcement found.
Structural Deformation	None detected.
Soil Stability	N/A
Other	N/A

General Condition of Channel for Future Structural Repair/Modification:

Spatial Limitations for Any Repair/Modification	Heavy vegetation found throughout the reach. See Picture #1. Apartment buildings are found on both sides of the channel (just outside of channel lining).

Summary and Conclusions:

Summary of Investigation:
No significant damage has been incurred by the channel throughout the reach.

Conclusions and Recommendations:
The overall condition of the channel is good.

Structural Life Expectancy: 15-20 yrs

P 13B Picture #1

SUMMARY REPORT OF SITE INVESTIGATION

General Information:

Creek Name: Permanente Creek	*SCVWD Reach No.*: P 14
Location: U/S to D/S Calif./El Camino culvert	*Channel Type*: Concrete Box Culvert
Date of Original Construction: 1963-1964	*Date of Inspection*: 7/27/99

General Dimensions:

Channel Height: Ranges from 8ft to 11ft	*Convention*: Looking Up-Station
Channel Width at Top: Ranges from 9ft to 12ft	*Channel Slope Left*: N/A
Channel Width at Bottom: Same as above.	*Channel Slope Right*: N/A

General Condition of Reach:

CONCERNS	*GENERAL REMARKS*
Concrete Cracks	Three cracks (two moderate and one minor) were found at three separate locations along the reach. An example of the cracks found is shown in Picture #1.
Surface Defects	Moderate efflorescence and staining were found at most joints throughout the reach. See Picture #2. Severe abrasion of the invert slab was found along 5% of the reach. See Picture #3. Moderate abrasion of the slab was found sporadically along the reach.
Reinforcement	Moderate exposed reinforcement was found along 5% of the reach-either at the base of the walls or along the invert slab. See Picture #4.
Structural Deformation	None detected.
Soil Stability	N/A
Other	The top slab has two locations where the reinforcement is exposed.

General Condition of Channel for Future Structural Repair/Modification:

Spatial Limitations for Any Repair/Modification	N/A

Summary and Conclusions:

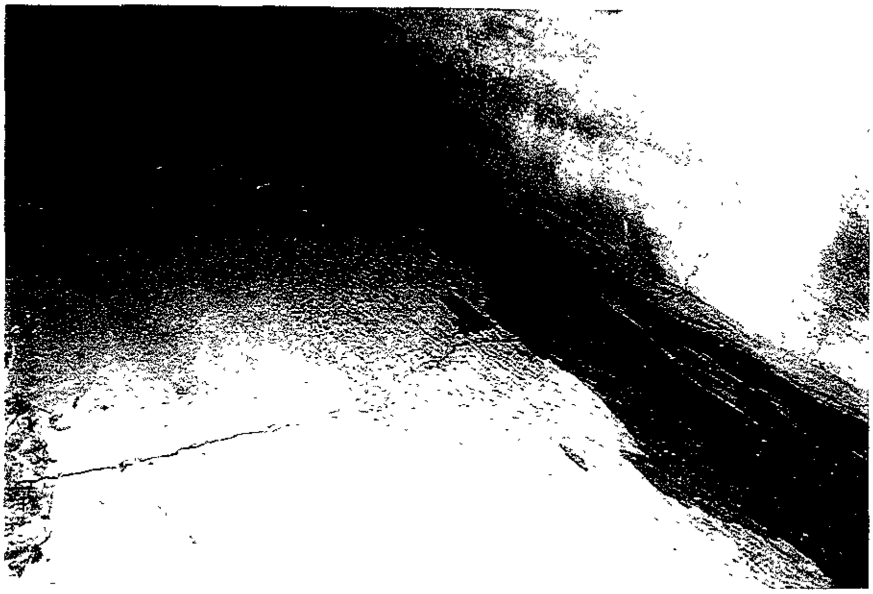
Summary of Investigation:

Three cracks were found at three separate locations along the reach. The exact cause(s) of these cracks is not certain. However, the cracks are not considered to be of significant structural concern. The moderate efflorescence and staining found at most joints throughout the reach are expected to occur during the service life of the culvert. Abrasion of the invert is expected, but the locations of severe abrasion are most likely due to localized weak concrete (a construction quality control issue). Overall, the structural integrity of the reach is good.

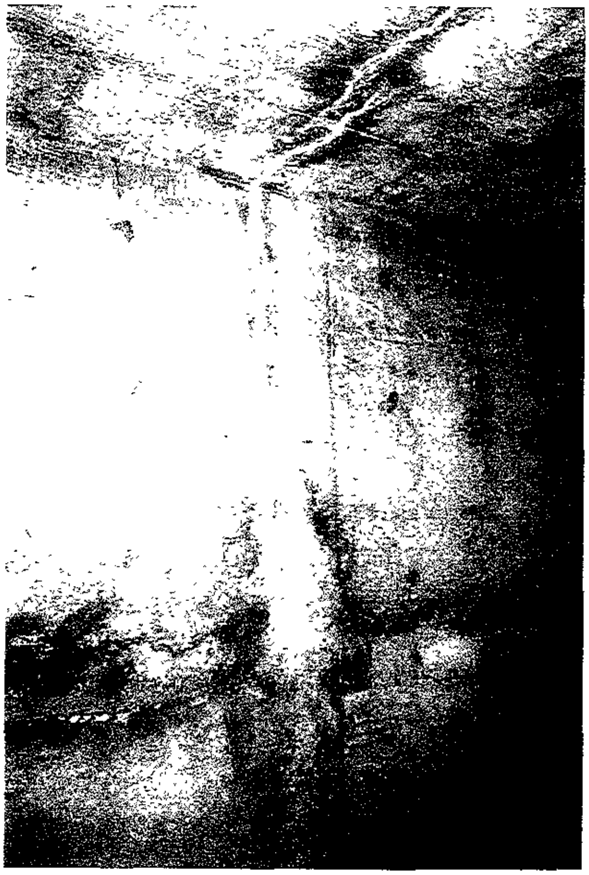
Conclusions and Recommendations:

Minor maintenance of the culvert such as patching the invert slab where the reinforcement is exposed is recommended. Otherwise, the overall condition of the reach is good.

Structural Life Expectancy: 20-25 yrs

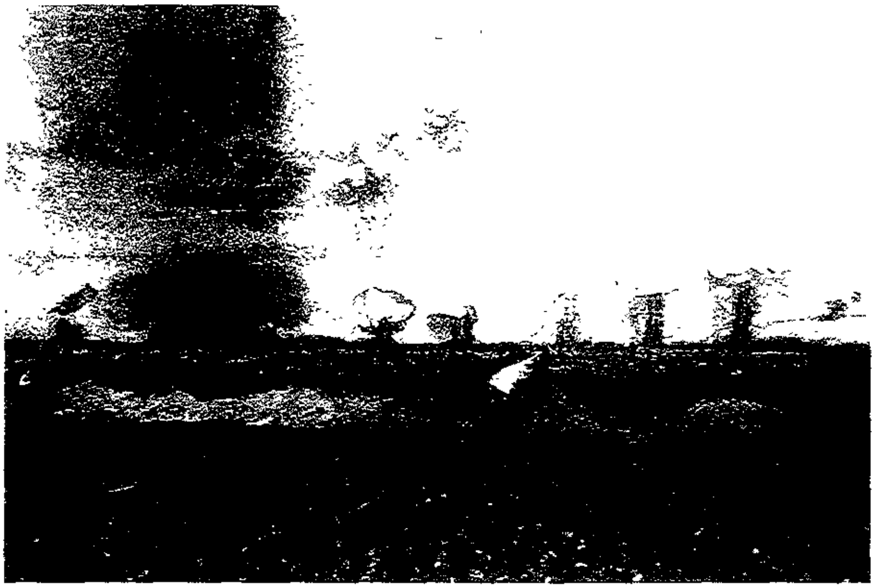


P 14 Picture #1



P 14 Picture #2

P 14 Picture #3



P 14 Picture #4

SUMMARY REPORT OF SITE INVESTIGATION

General Information:

Creek Name: Permanente Creek	*SCVWD Reach No.*: P 15A
Location: Calif./El Camino culvert to Park Dr.	*Channel Type*: Concrete U-Frame
Date of Original Construction: 1962	*Date of Inspection*: 7/27/99

General Dimensions:

Channel Height: Ranges from 8ft to 11ft	*Convention*: Looking Up-Station
Channel Width at Top: Ranges from 11ft to 12ft	*Channel Slope Left*: N/A
Channel Width at Bottom: Same as above.	*Channel Slope Right*: N/A

General Condition of Reach:

CONCERNS	*GENERAL REMARKS*
Concrete Cracks	Moderate vertical temperature cracks were found along the entire reach. See Picture #1 as an example.
Surface Defects	No notable surface defects found.
Reinforcement	No exposed reinforcement found. However, most likely the main vertical wall steel has yielded and corroded.
Structural Deformation	Severe to moderate wall deflections were found along the entire reach. Max. deflection found to be 5.8 times yield displacement. See Picture #2 as an example.
Soil Stability	N/A
Other	N/A

General Condition of Channel for Future Structural Repair/Modification:

Spatial Limitations for Any Repair/Modification	Heavy vegetation, residential housing (approx. 10ft offset from walls), and a chain link fence above both walls. See Picture #3.

Summary and Conclusions:

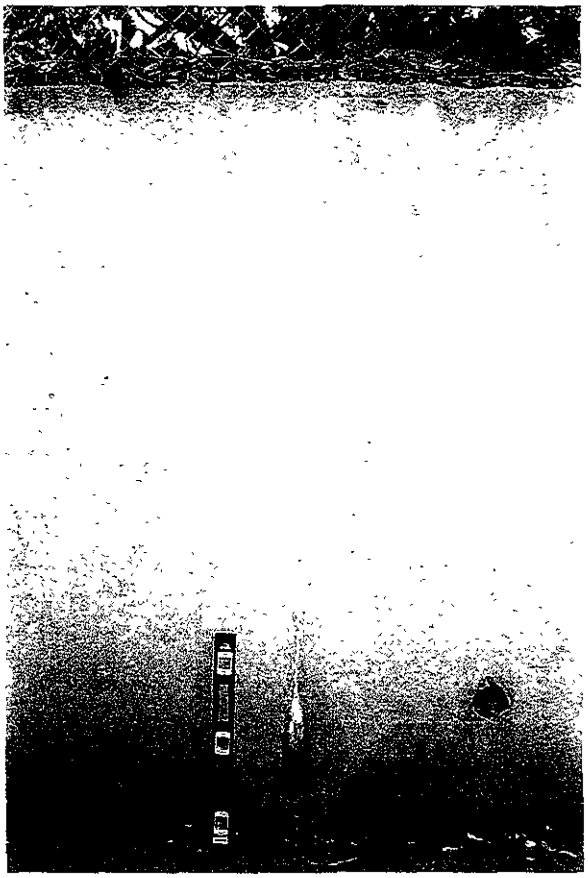
Summary of Investigation:

The condition of the reach, as it pertains to surface defects is good. However, excessive wall deflections were found along the entire reach. These excessive wall deflections are most likely due to a wall design load which is less than the actual load the walls resist.

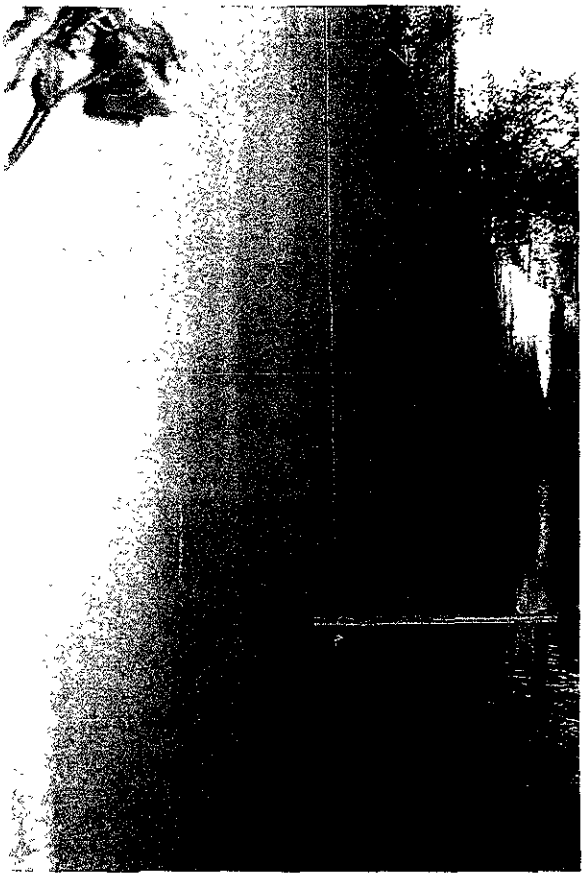
Conclusions and Recommendations:

Since the vertical walls of the reach have sustained moderate to severe wall deflections, we recommend rehabilitation of the existing U-Frame channel for reach P15A within the next 10 years.

Structural Life Expectancy: 5-10 yrs (U-Frame only) 20-25 yrs (Box Culvert)



P 15A Picture #1



P 15A Picture #2

P 15A Picture #3

SUMMARY REPORT OF SITE INVESTIGATION

General Information:

Creek Name: Permanente Creek	*SCVWD Reach No.*: P 15B
Location: Park Drive to Mt. View Ave.	*Channel Type*: Concrete U-Frame
Date of Original Construction: 1962	*Date of Inspection*: 7/28/99

General Dimensions:

Channel Height: Ranges from 6.5ft to 11ft	*Convention*: Looking Up-Station
Channel Width at Top: 12ft	*Channel Slope Left*: N/A
Channel Width at Bottom: 12ft	*Channel Slope Right*: N/A

General Condition of Reach:

CONCERNS	*GENERAL REMARKS*
Concrete Cracks	Moderate vertical temperature cracks were found along the entire reach. See Picture #1 as an example.
Surface Defects	No notable surface defects found.
Reinforcement	No exposed reinforcement found. However, most likely the main vertical wall steel has yielded and corroded.
Structural Deformation	Severe wall deflections found throughout the reach. Max. deflection found to be 18.9 times yield displacement. See Picture #2.
Soil Stability	N/A
Other	N/A

General Condition of Existing Structural Repairs/Modifications:

Description of Existing Repairs/Modifications	*Constructed*: 1999	Soil nails installed at approximately midheight and bottom of walls. See Picture #3.
Spatial Limitations for Any Repairs/Modifications	Heavy vegetation, residential housing (approx. 10ft offset from walls), and a chain link fence above both walls. See Picture #4.	

Summary and Conclusions:

Summary of Investigation:

The condition of the reach, as it pertains to surface defects is good. However, both vertical walls of the U-Frame channel have experienced excessive deflections due to unaccounted for loads and the corrosion of the main wall steel throughout the reach. The existing soil nail repair has not corrected the excessive deformations of the walls. The locations of the soil nails along the walls lead us to believe that this repair is an inefficient solution. Currently, it is unknown whether the repair has curtailed the walls from further deflection.

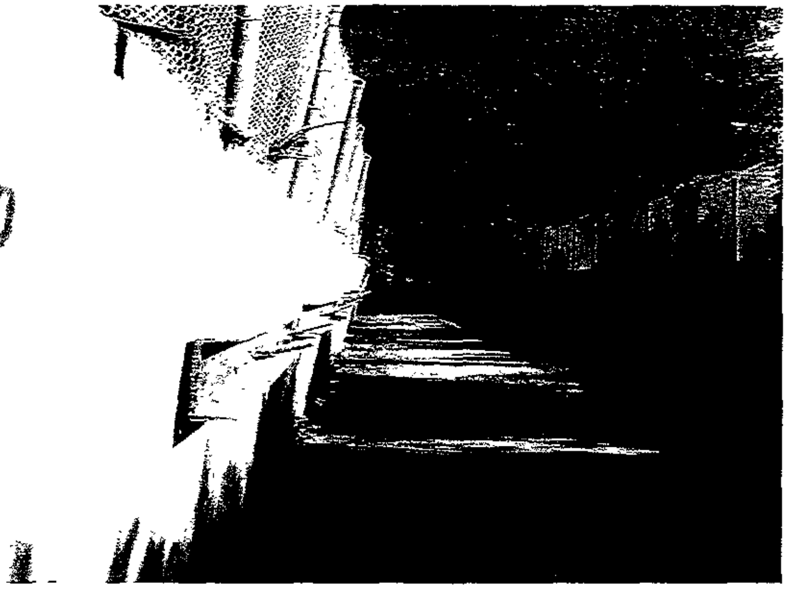
Conclusions and Recommendations:

Since the vertical walls of the reach have sustained severe wall deflections, we recommend the immediate rehabilitation of the existing U-Frame channel for reach P 15B.

Structural Life Expectancy: 0-5 yrs

P 15B Picture #1

P 15B Picture #2



P 15B Picture #3

P 15B Picture #4

SUMMARY REPORT OF SITE INVESTIGATION

General Information:

Creek Name: Permanente Creek	*SCVWD Reach No.*: P 16
Location: Mt. View Ave. to Hale Creek confluence	*Channel Type*: Mostly Concrete U-Frame
Date of Original Construction: 1962	*Date of Inspection*: 7/28/99

General Dimensions:

Channel Height: Ranges from 6.5ft to 7ft	*Convention*: Looking Up-Station
Channel Width at Top: Mostly 12ft	*Channel Slope Left*: Mostly N/A
Channel Width at Bottom: Mostly 12ft	*Channel Slope Right*: Mostly N/A

General Condition of Reach:

CONCERNS	*GENERAL REMARKS*
Concrete Cracks	Moderate vertical temperature cracks were found along the entire reach. See Picture #1.
Surface Defects	Moderate to minor pop-outs were found along 20% of reach. See Picture #2. Moderate abrasion was found sparsely along the base of channel walls. See Picture #3. Moderate staining was found along 15% of reach (same location as vertical cracks).
Reinforcement	Moderate to minor exposed reinforcement was found sparsely along the reach-primarily at the base of the channel walls. See Picture #4.
Structural Deformation	Severe to moderate wall deflections found along the entire reach. Max. deflection found to be 7.3 times yield displacement. See Picture #5.
Soil Stability	N/A
Other	N/A

General Condition of Channel for Future Structural Repair/Modification:

Spatial Limitations for Any Repair/Modification	Chain link fence above both channel walls, residential housing (approx. 2ft offset from walls) and vegetation along either side of channel.

Summary and Conclusions:

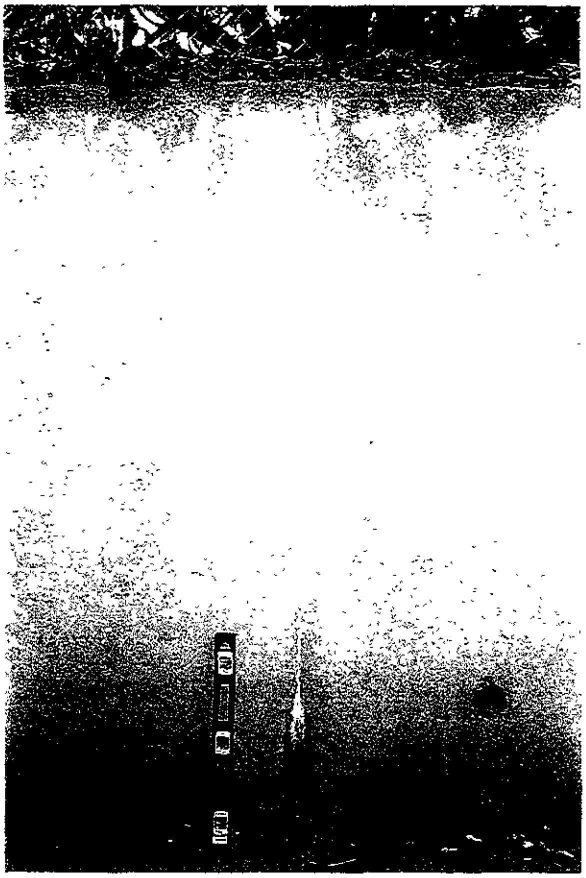
Summary of Investigation:

Excessive wall deflections have been detected throughout the reach. These excessive wall deflections are most likely due to a wall design load which is less than the actual load the walls resist. The pop-outs and exposed reinforcement found along the reach can be attributed to the lack of concrete cover. The vertical cracks and accompanying stains reveal that these cracks have penetrated the entire wall and that water (from behind the wall) is draining through them.

Conclusions and Recommendations:

Since the vertical walls of the reach have sustained moderate to severe wall deflections, we recommend rehabilitation of the existing U-Frame channel for reach P 16 within the next 5 years.

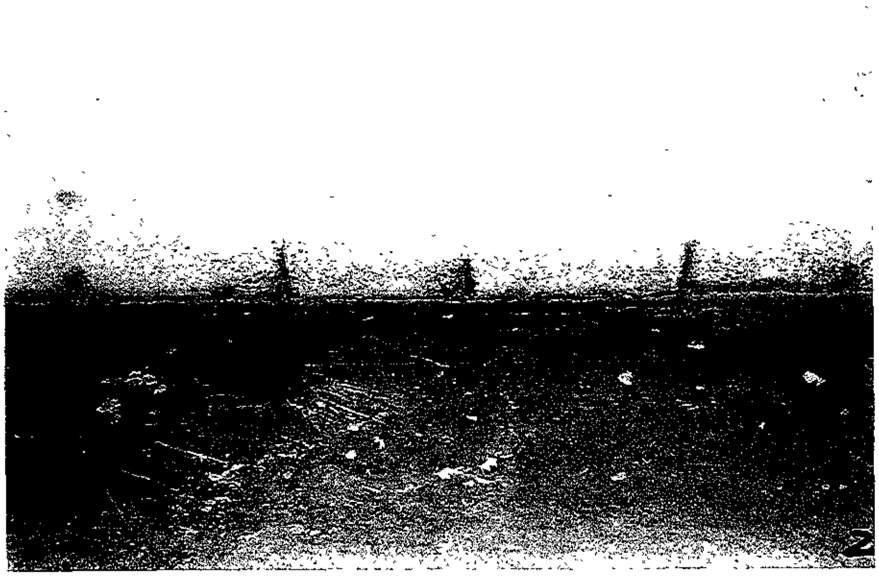
Structural Life Expectancy: 0-5 yrs (U-Frame only) 20-25 yrs (Box Culvert)



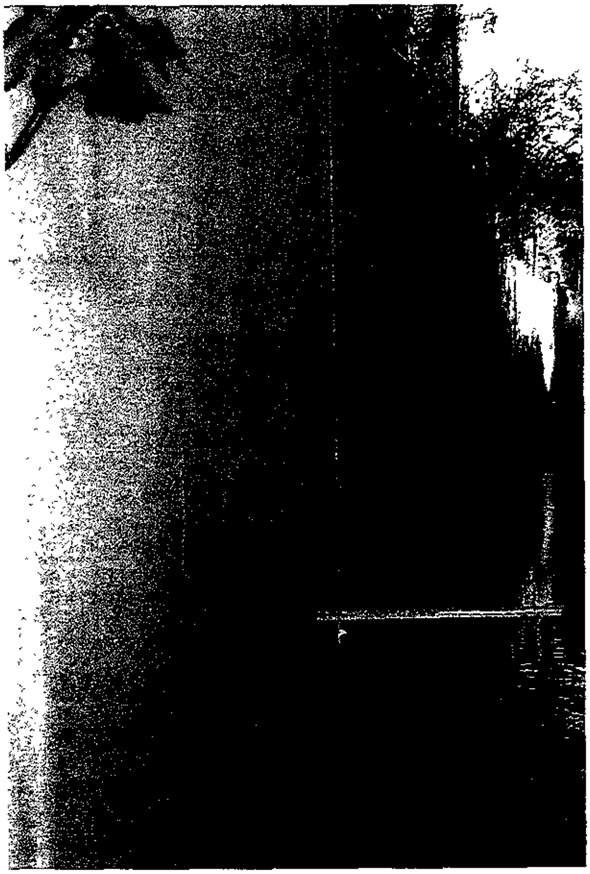
P 16 Picture #1

P 16 Picture #2

P 16 Picture #3



P 16 Picture #4



P 16 Picture #5

SUMMARY REPORT OF SITE INVESTIGATION

General Information:

Creek Name: Permanente Creek	*SCVWD Reach No.*: P 20
Location: Cuesta Dr. culvert to St. Francis HS	*Channel Type*: Concrete Arch Culvert
Date of Original Construction: 1956	*Date of Inspection*: 7/29/99

General Dimensions:

Channel Height: 7.5ft	*Convention*: Looking Up-Station
Channel Width at Top: N/A	*Channel Slope Left*: N/A
Channel Width at Bottom: 14.3ft	*Channel Slope Right*: N/A

General Condition of Reach:

CONCERNS	*GENERAL REMARKS*
Concrete Cracks	Concrete appears to be in good condition.
Surface Defects	Minor staining found along base of walls. See Picture #1.
Reinforcement	No exposed reinforcement found.
Structural Deformation	None detected.
Soil Stability	N/A
Other	See Picture #2 for an overall view of the culvert.

General Condition of Channel for Future Structural Repair/Modification:

Spatial Limitations for Any Repair/Modification	N/A

Summary and Conclusions:

Summary of Investigation:

For reach P 20, no significant damage has been incurred by to date. Thus, the overall condition of the reach as it relates to its structural integrity is good.

Conclusions and Recommendations:

The overall condition of the reach is good.

Structural Life Expectancy: 10-15 yrs

P 20 Picture #1

P 20 Picture #2

SUMMARY REPORT OF SITE INVESTIGATION

General Information:

Creek Name: Permanente Creek	*SCVWD Reach No.*: P 23
Location: Permanente conflu. to Portland Ave.	*Channel Type*: Concrete Trapezoidal
Date of Original Construction: 1981	*Date of Inspection*: 7/30/99 and 8/24/99

General Dimensions:

Channel Height: Ranges from 9ft to 10ft	*Convention*: Looking Up-Station
Channel Width at Top: Ranges from 27ft to 42ft	*Channel Slope Left*: Ranges from 1.5:1 to 1:1
Channel Width at Bottom: Ranges from 9ft to 15ft	*Channel Slope Right*: Ranges from 1.5:1 to 1:1

General Condition of Reach:

CONCERNS	*GENERAL REMARKS*
Concrete Cracks	Moderate shear crack found in arch culvert. See Picture #1.
Surface Defects	Severe spalling found at one location. See Picture #2. Moderate pop-outs were found on the walls of the arch culvert. See Picture #3. Minor abrasion was found along 30% of reach. See Picture #4.
Reinforcement	Moderate exposed reinforcement was found at one joint (see Picture #2) and at the moderate pop-outs (see Picture #3).
Structural Deformation	None detected.
Soil Stability	N/A
Other	N/A

General Condition of Channel for Future Structural Repair/Modification:

Spatial Limitations for Any Repair/Modification	Fence found on both sides of channel (approx. 5ft offset from top of channel). Pedestrian bridge crosses channel at one location. See Picture #5.

Summary and Conclusions:

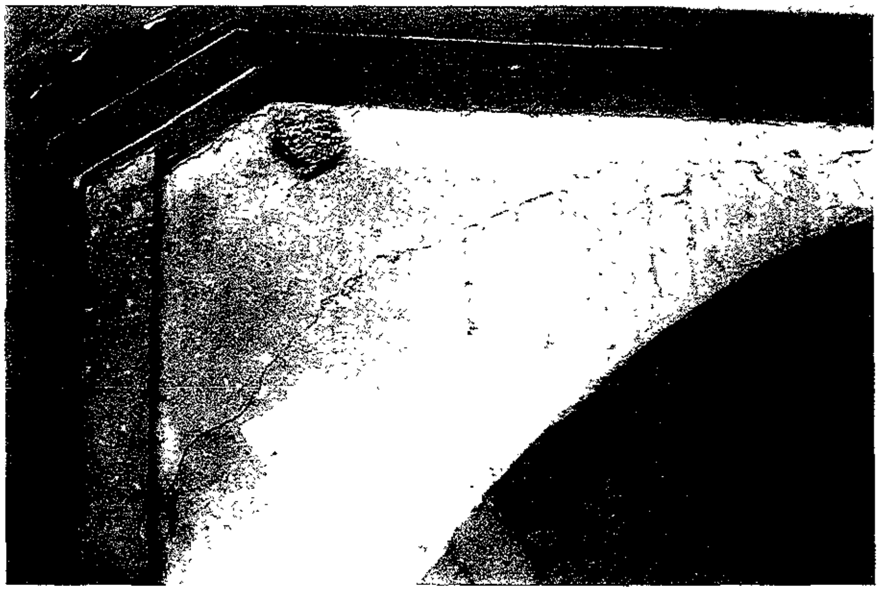
Summary of Investigation:

The damage incurred by the channel to date is minor as it relates to the reach's overall structural integrity. The cracks and surface defects found are expected to occur during the service life of the channel. Thus, the overall condition of the reach as it pertains to its structural integrity is good.

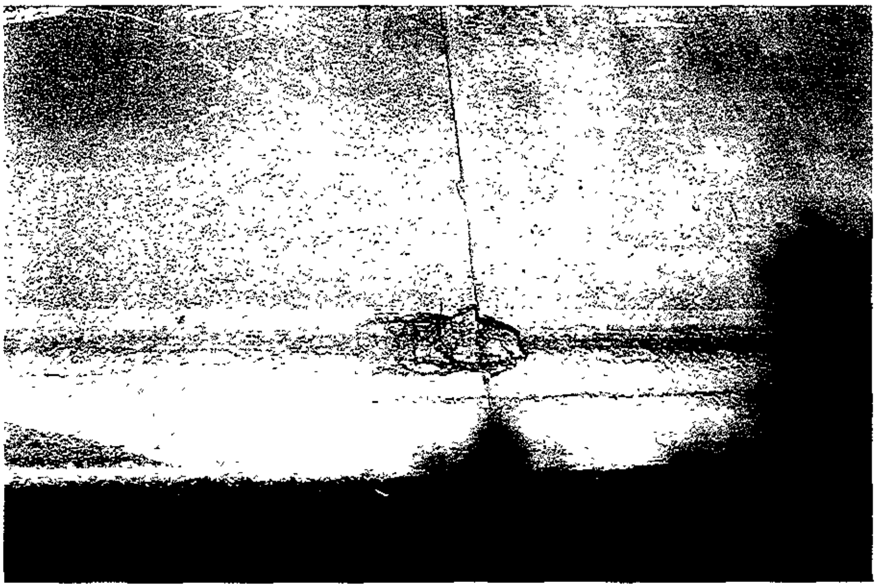
Conclusions and Recommendations:

The overall condition of the reach is good.

Structural Life Expectancy: 35-40 yrs (Trap. Channel only) 20-25 yrs (Box Culvert)

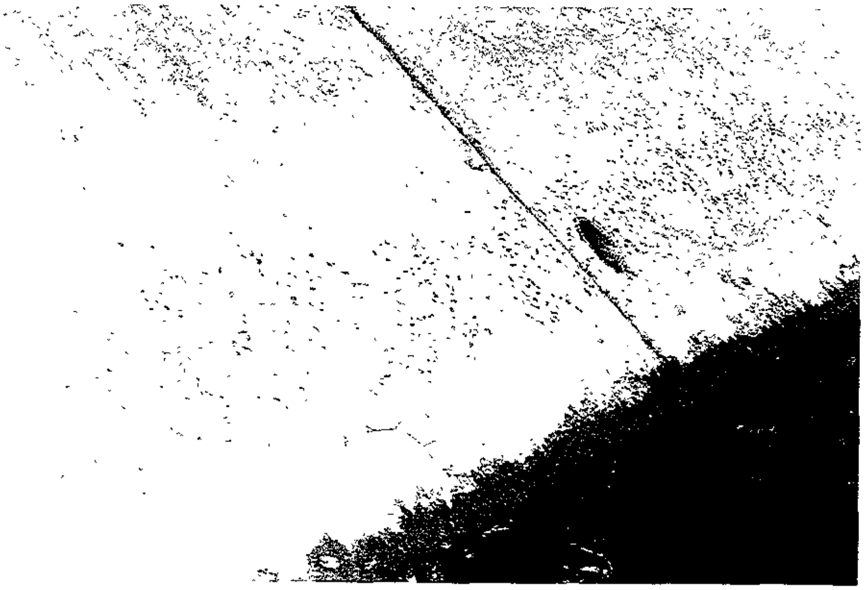


P 23 Picture #1

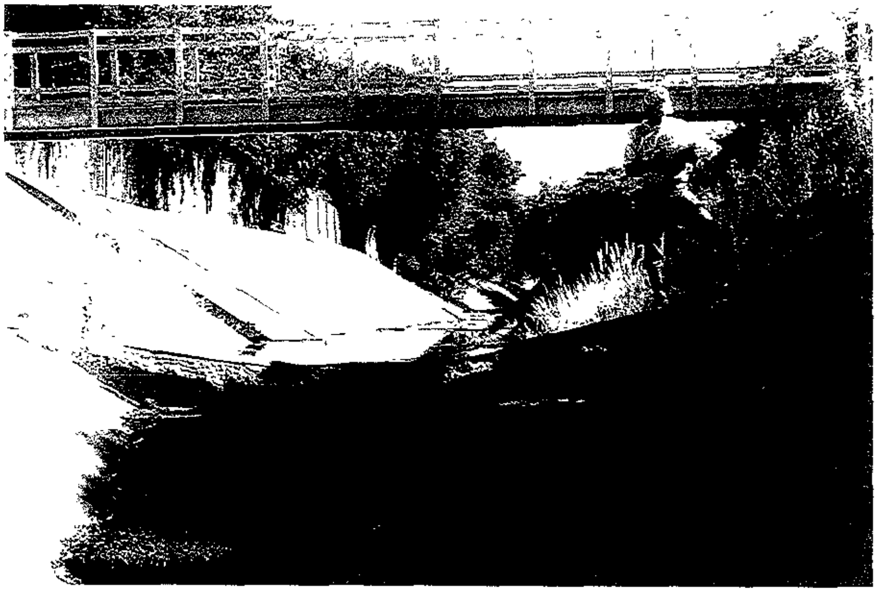


P 23 Picture #2

P 23 Picture #3



P 23 Picture #4



P 23 Picture #5

SUMMARY REPORT OF SITE INVESTIGATION

General Information:

Creek Name: Permanente Diversion	*SCVWD Reach No.*: PD 1
Location: Stevens Creek confluence to Diericx Dr.	*Channel Type*: Concrete Trapezoidal
Date of Original Construction: 1959	*Date of Inspection*: 7/29/99

General Dimensions:

Channel Height: Ranges from 10ft to 11ft	*Convention*: Looking Up-Station
Channel Width at Top: Ranges from 10ft to 36ft	*Channel Slope Left*: 1:1
Channel Width at Bottom: Ranges from 10ft to 14ft	*Channel Slope Right*: 1:1

General Condition of Reach:

CONCERNS	*GENERAL REMARKS*
Concrete Cracks	Moderate horizontal and vertical cracks were found along the entire reach. See Picture #1.
Surface Defects	Moderate spalling was found at two joints along the reach. See Picture #2.
Reinforcement	No exposed reinforcement was found.
Structural Deformation	None detected.
Soil Stability	N/A
Other	Vegetation was found growing out of the joints and weep holes. See Picture #3.

General Condition of Channel for Future Structural Repair/Modification:

Spatial Limitations for Any Repair/Modification	Fence found on both sides of the channel (approx. 4ft offset left and 20ft offset right from top of lining, looking up-station).

Summary and Conclusions:

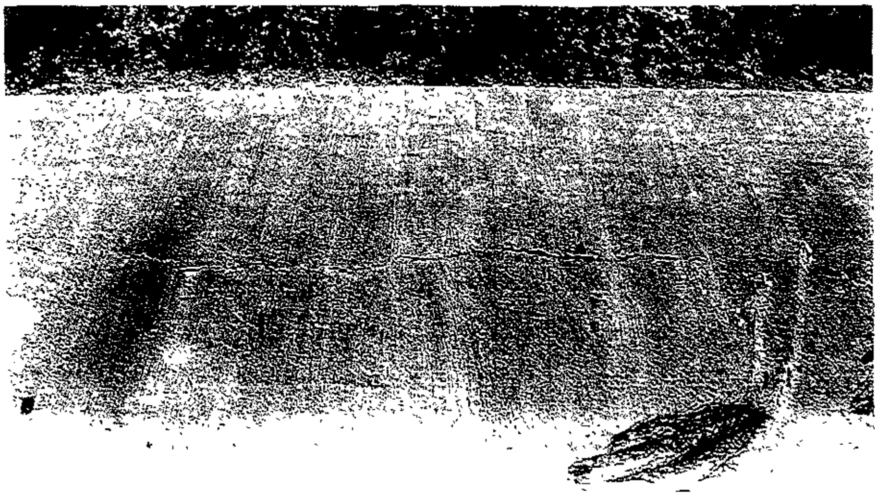
Summary of Investigation:

The moderate horizontal and vertical cracks found along the entire reach are due to unaccounted for loads resisted by the channel lining. The moderate spalling found at the joints are most likely due to pounding of adjacent channel segments during a seismic event. The concrete cracks and spalls incurred by the channel will reduce its structural life expectancy.

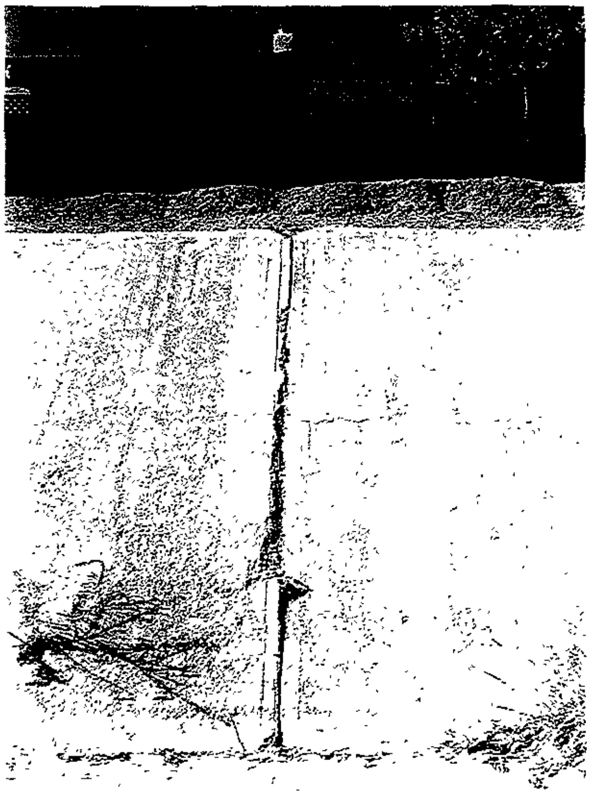
Conclusions and Recommendations:

Since the channel has incurred the damage specified above, we recommend the replacement of the trapezoidal channel lining for reach PD 1 within the next 10 years.

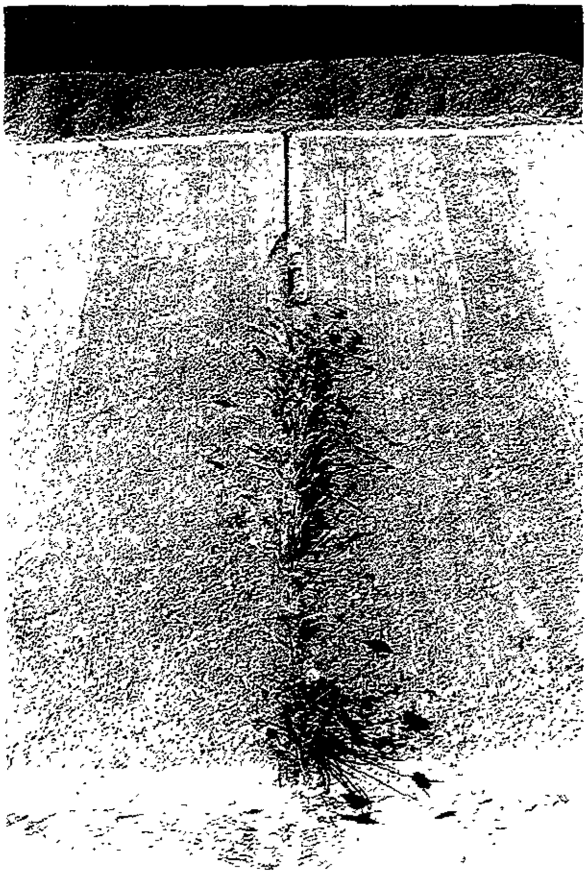
Structural Life Expectancy: 5-10 yrs (Trap. Channel only) 20-25 yrs (Box Culvert)



PD 1 Picture #1



PD 1 Picture #2



PD 1 Picture #3

SUMMARY REPORT OF SITE INVESTIGATION

General Information:

Creek Name: Permanente Diversion	*SCVWD Reach No.*: PD 2
Location: Diericx Dr. to Grant Rd.	*Channel Type*: Concrete Trapezoidal
Date of Original Construction: 1959	*Date of Inspection*: 7/30/99

General Dimensions:

Channel Height: Mostly 10ft	*Convention*: Looking Up-Station
Channel Width at Top: Mostly 35ft	*Channel Slope Left*: 1:1
Channel Width at Bottom: Mostly 15ft	*Channel Slope Right*: 1:1

General Condition of Reach:

CONCERNS	*GENERAL REMARKS*
Concrete Cracks	Moderate horizontal and vertical cracks were found along the entire reach. See Picture #1. Minor pattern cracking was found at one location. See Picture #2.
Surface Defects	Moderate spalling was found at 12 separate joints. See Picture #3 for typical example.
Reinforcement	Minor to moderate exposed reinforcement was found at two locations. See Picture #4.
Structural Deformation	None detected.
Soil Stability	N/A
Other	Numerous weep holes were found clogged along the reach.

General Condition of Channel for Future Structural Repair/Modification:

Spatial Limitations for Any Repair/Modification	Fences and utility poles were found on both sides of the channel (approx. 10ft offset left and 20ft offset right). Utility pipes and bridges crossing the channel were found sporadically along the reach. See Picture #5.

Summary and Conclusions:

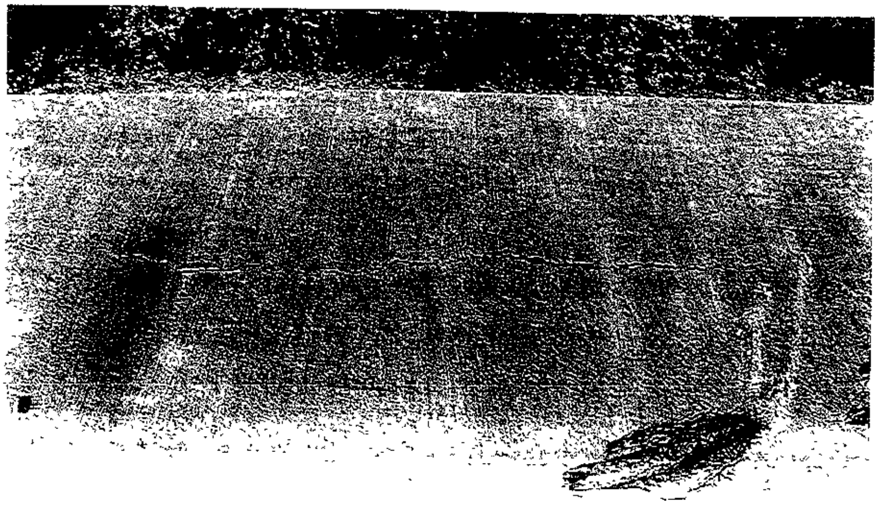
Summary of Investigation:

The moderate horizontal and vertical cracks found along the entire reach are due to unaccounted for loads resisted by the channel lining. The moderate spalling and exposed dowels found at the joints are most likely due to pounding of adjacent channel segments during a seismic event. The minor pattern cracking found is not of significant concern since such surface defects are expected to occur sometime during the service life of the channel. The concrete cracks and spalls, however, incurred by the channel will reduce its structural life expectancy.

Conclusions and Recommendations:

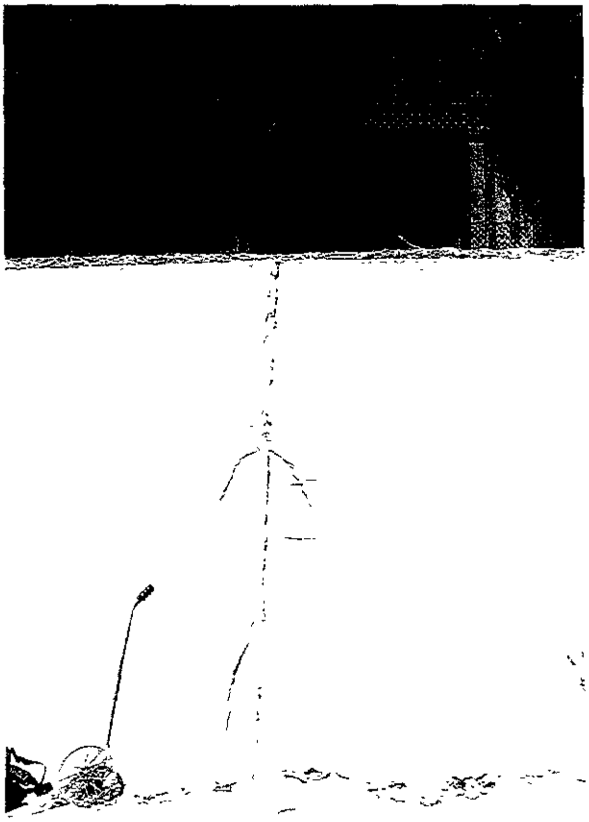
Since the channel has incurred the damage specified above, we recommend the replacement of the trapezoidal channel lining for reach PD 2 within the next 10 years.

Structural Life Expectancy: 5-10 yrs



PD 2 Picture #1

PD 2 Picture #2



PD 2 Picture #3

PD 2 Picture #4

PD 2 Picture #5

SUMMARY REPORT OF SITE INVESTIGATION

General Information:

Creek Name: Permanente Diversion	*SCVWD Reach No.*: PD 3
Location: Grant Rd. to Carmel Terrace	*Channel Type*: Mostly Concrete U-Frame
Date of Original Construction: Mostly 1986	*Date of Inspection*: 7/30/99

General Dimensions:

Channel Height: Ranges from 9ft to 14ft	*Convention*: Looking Up-Station
Channel Width at Top: Ranges from 27ft to 47ft	*Channel Slope Left*: N/A
Channel Width at Bottom: Ranges from 27ft to 47ft	*Channel Slope Right*: N/A

General Condition of Reach:

CONCERNS	*GENERAL REMARKS*
Concrete Cracks	Moderate horizontal and/or vertical cracks were found along the entire reach. See Picture #1.
Surface Defects	Moderate efflorescence was found on 50% of reach. See Picture #1. Moderate spalling was found at 4 separate joints. See Picture #2. Moderate pop-outs were found on 60% of the reach. See Picture #3.
Reinforcement	Moderate exposed reinforcement found at two joints. See Picture #2.
Structural Deformation	Moderate wall deflections were found along 60% of reach. Max. deflection found to be slightly less than the yield displacement. See Picture #4.
Soil Stability	N/A
Other	N/A

General Condition of Channel for Future Structural Repair/Modification:

Spatial Limitations for Any Repair/Modification	Fence found on both sides of the channel (left offset varies from 0ft to 10ft and right offset varies from 0ft to 20ft). Pedestrian bridge crosses the channel at one location. See Picture #5.

Summary and Conclusions:

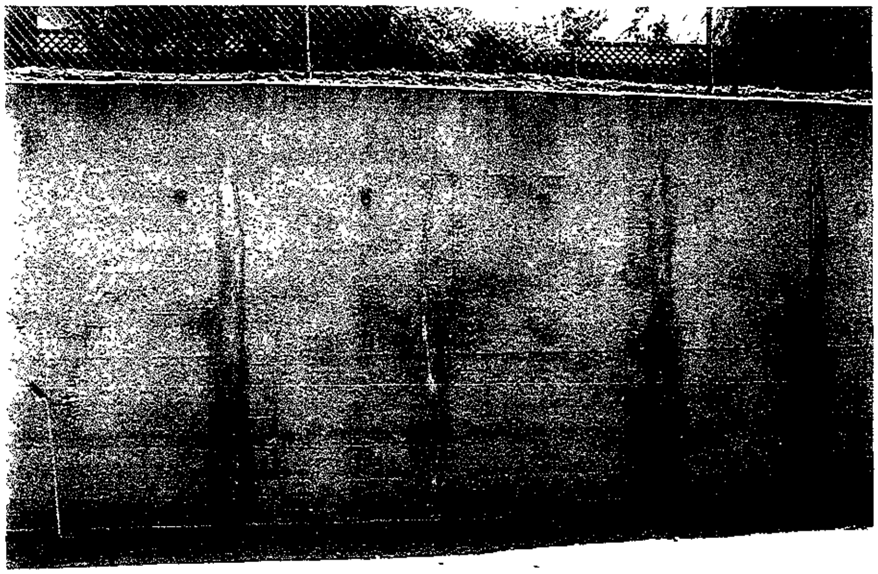
Summary of Investigation:

The moderate vertical cracks found along the U-frame portion of the reach are due to temperature expansion and contraction. While the moderate horizontal cracks found along the trapezoidal portion are due to unaccounted for loads resisted by the channel lining. The moderate spalling and exposed reinforcement found at the joints are most likely due to pounding of adjacent channel sections during a seismic event. The moderate efflorescence found along 50% of the reach is due to irrigation water seeping through the vertical cracks of the walls. The cracks and spalls incurred by the trapezoidal section will reduce its structural life expectancy.

Conclusions and Recommendations:

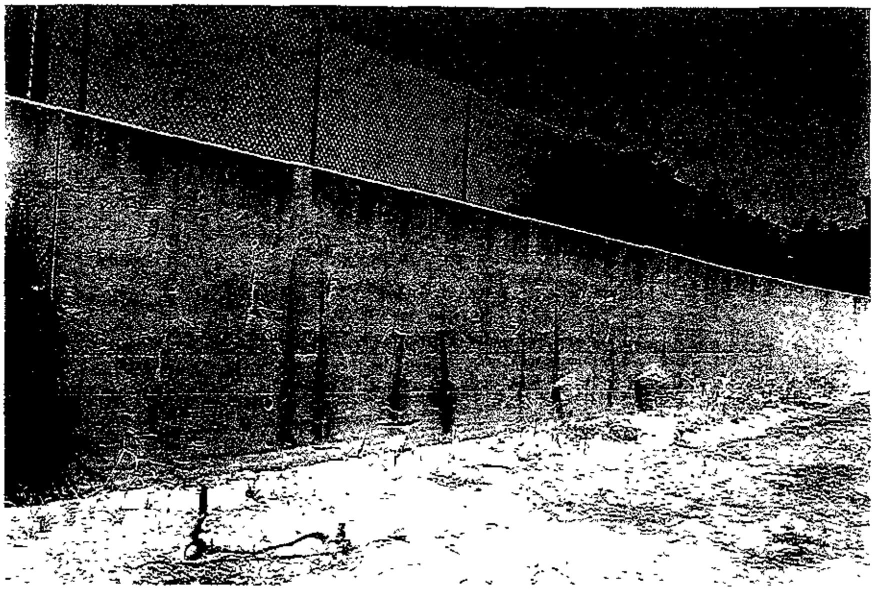
Since the vertical walls have sustained moderate wall deflections, we recommend the rehabilitation of the U-Frame channel for reach PD 3 within the next 20 years. However, since the trapezoidal channel of reach has incurred the damage specified above, we recommend the replacement of the channel lining for reach PD 3 within the next 10 years.

Structural Life Expectancy: 15-20 yrs (U-Frame only) 5-10 yrs (Trap. Channel)

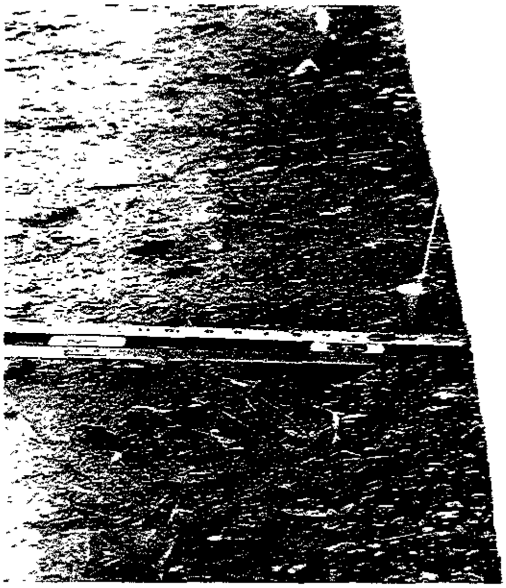


PD 3 Picture #1

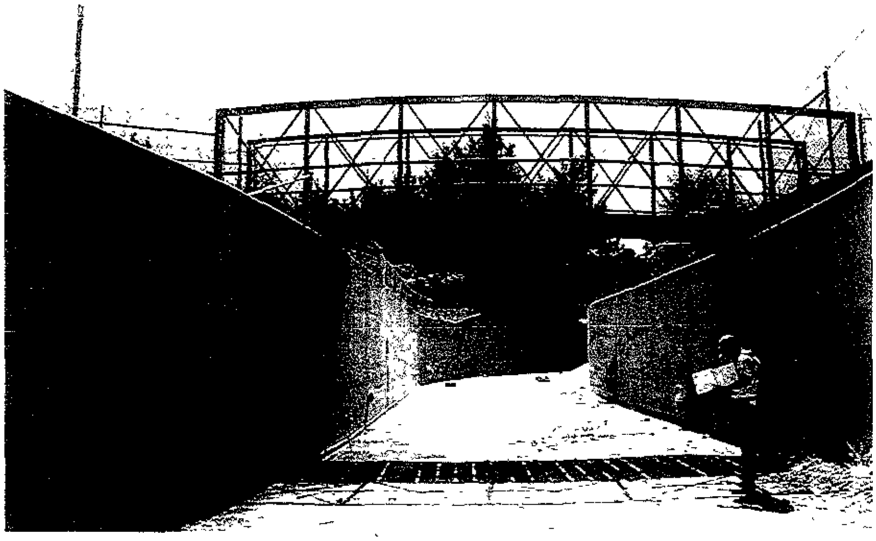
PD 3 Picture #2



PD 3 Picture #3



PD 3 Picture #4



PD 3 Picture #5

SUMMARY REPORT OF SITE INVESTIGATION

General Information:

Creek Name: Permanente Diversion	*SCVWD Reach No.*: PD 4
Location: Carmel Terrace to Permanente conflu.	*Channel Type*: Mostly Concrete Trapezoidal
Date of Original Construction: Mostly 1959	*Date of Inspection*: 7/30/99

General Dimensions:

Channel Height: Ranges from 9ft to 14ft	*Convention*: Looking Up-Station
Channel Width at Top: Ranges from 14ft to 36ft	*Channel Slope Left*: 1:1
Channel Width at Bottom: Ranges from 9ft to 14ft	*Channel Slope Right*: 1:1

General Condition of Reach:

CONCERNS	*GENERAL REMARKS*
Concrete Cracks	Moderate horizontal and vertical cracks were found along the entire reach. See Picture #1. Joint separation crack found at two joints. See Picture #2.
Surface Defects	Moderate efflorescence was found on 25% of reach. See Picture #3. Moderate pop-outs were found on 25% of reach. Moderate spalling was found at three separate joints. See Picture #4. Severe abrasion was found on the invert slab at one drop structure. See Picture #5.
Reinforcement	Severe exposed reinforcement was found on the invert slab at one drop structure. See Picture #5.
Structural Deformation	Moderate wall deflections were found on 20% of the reach. Max. deflection found to be slightly less than the yield displacement. See Picture #6. Severe differential deflection was found at one location along the trapezoidal lining. See Picture #7.
Soil Stability	N/A
Other	N/A

General Condition of Channel for Future Structural Repair/Modification:

Spatial Limitations for Any Repair/Modification	Fence found on both sides of channel (approx. 10ft offset left and 20ft offset right).

Summary and Conclusions:

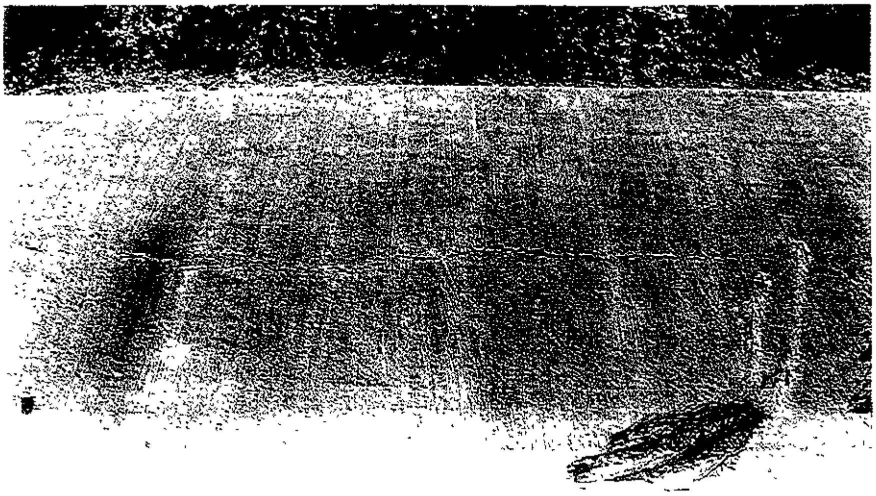
Summary of Investigation:

The moderate horizontal cracks found along the trapezoidal portion of the reach are due to unaccounted for loads resisted by the channel lining. The moderate vertical cracks found along the U-frame portion of the reach are due to temperature expansion and contraction. The moderate spalling found at the joints are most likely due to pounding of adjacent channel segments during a seismic event. The moderate efflorescence found along the reach is due to irrigation water seeping through the vertical cracks of the walls. . The cracks and spalls incurred by the trapezoidal section will reduce its structural life expectancy.

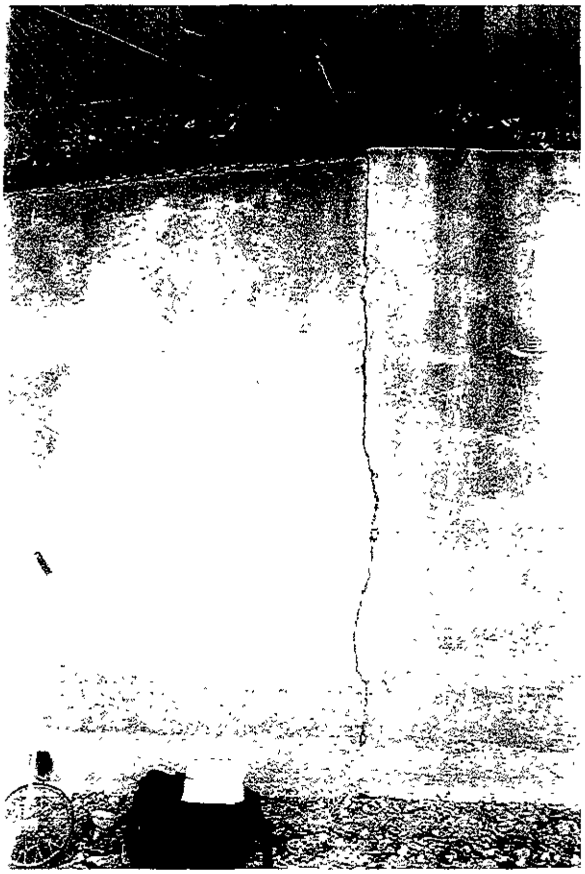
Conclusions and Recommendations:

Since the vertical walls have sustained moderate wall deflections, we recommend the rehabilitation of the U-Frame channel for reach PD 4 within the next 20 years. However, since the trapezoidal channel has incurred the damage specified above, we recommend the replacement of the channel lining within the next 10 years.

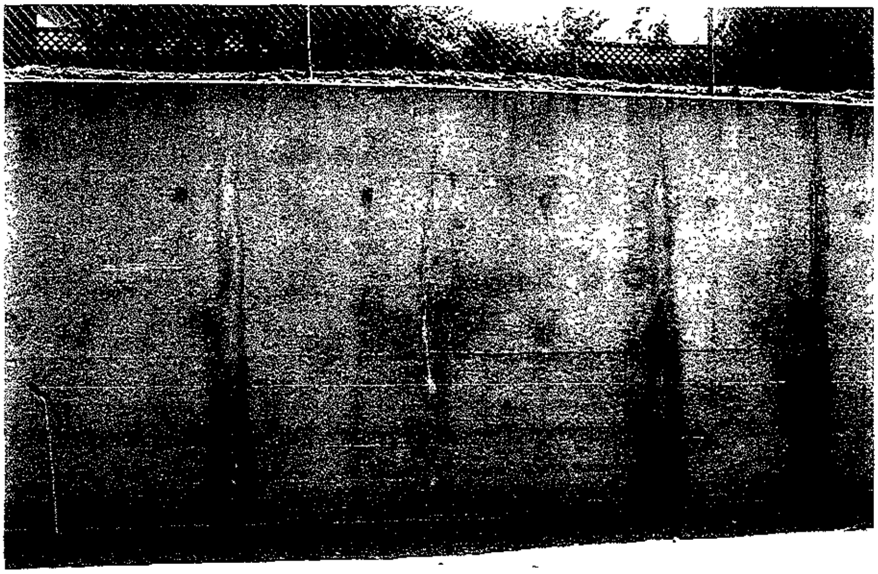
Structural Life Expectancy: 5-10 yrs (Trap. Channel only) 15-20 yrs (U-Frame)



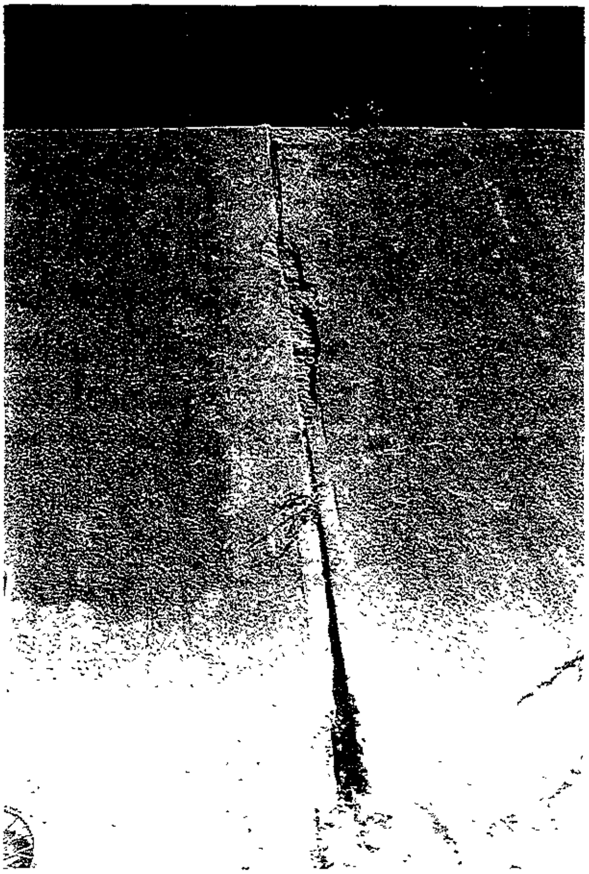
PD 4 Picture #1



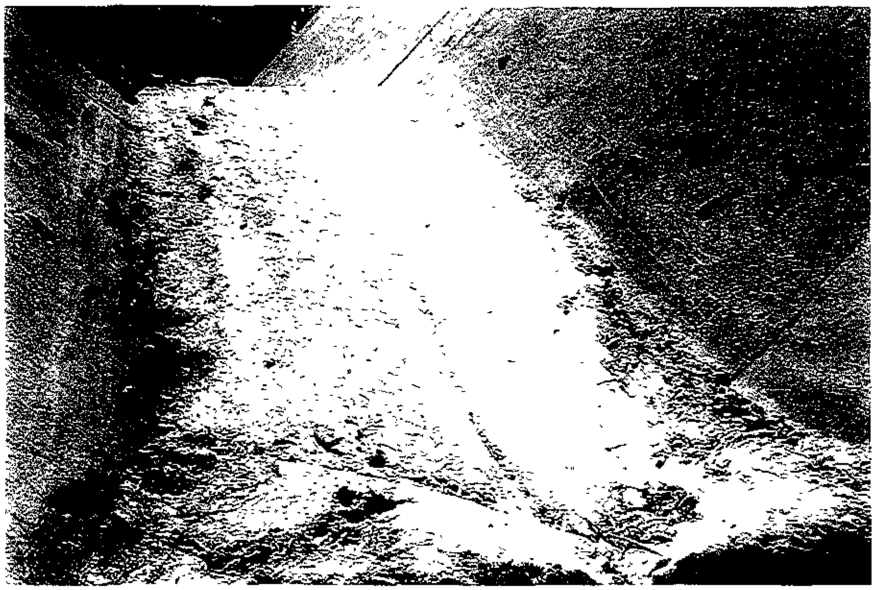
PD 4 Picture #2



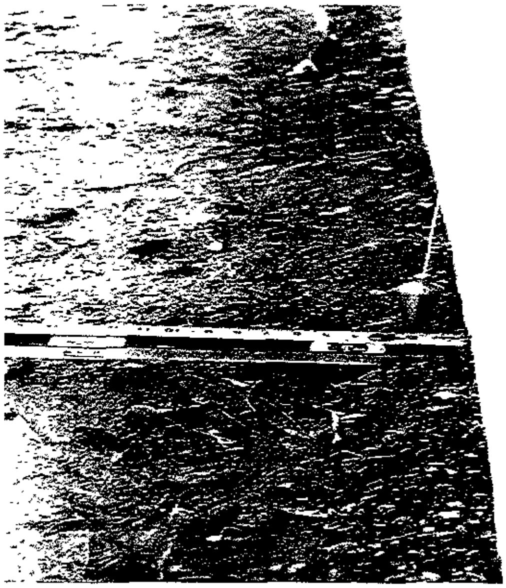
PD 4 Picture #3



PD 4 Picture #4



PD 4 Picture #5



PD 4 Picture #6

PD 4 Picture #7

SUMMARY REPORT OF SITE INVESTIGATION

General Information:

Creek Name: Hale Creek	*SCVWD Reach No.*: H 1A
Location: Hale Ck. confluence to Mt. View culvert	*Channel Type*: Concrete Trapezoidal
Date of Original Construction: 1960	*Date of Inspection*: 7/28/99

General Dimensions:

Channel Height: Ranges from 6.5ft to 10ft	*Convention*: Looking Up-Station
Channel Width at Top: Ranges from 22.25ft to 29ft	*Channel Slope Left*: 1:1
Channel Width at Bottom: Ranges from 9.3ft to 13ft	*Channel Slope Right*: 1:1

General Condition of Reach:

CONCERNS	*GENERAL REMARKS*
Concrete Cracks	Concrete appears to be in good condition.
Surface Defects	No notable surface defects detected.
Reinforcement	No exposed reinforcement found.
Structural Deformation	None detected.
Soil Stability	N/A
Other	See Picture #1 for overall view of reach.

General Condition of Channel for Future Structural Repair/Modification:

Spatial Limitations for Any Repair/Modification	Fences and residential housing on both sides of the channel (approx. 2ft offset from lining). Utility conduit crosses the channel at the Mt. View culvert. See Picture #2.

Summary and Conclusions:

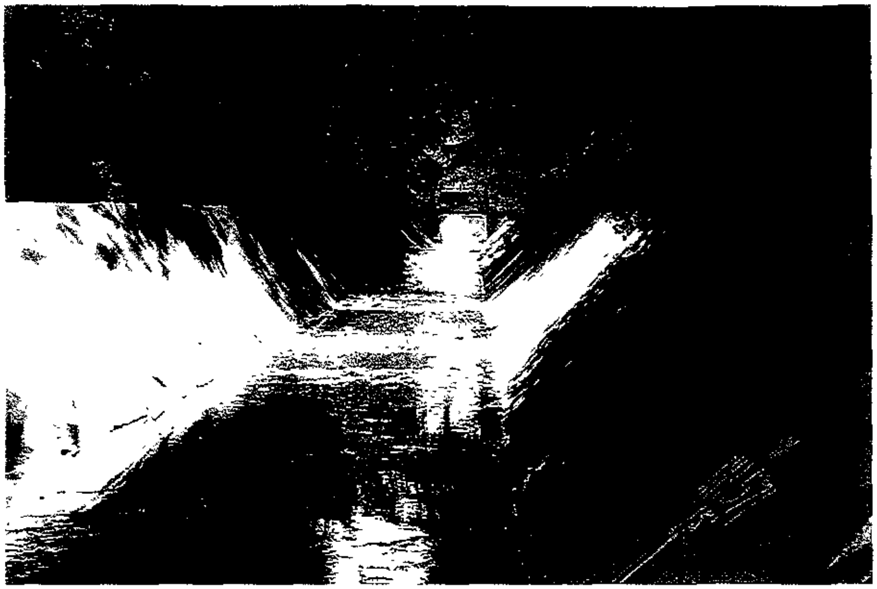
Summary of Investigation:

For reach H 1A, no significant damage has been incurred by the channel to date.

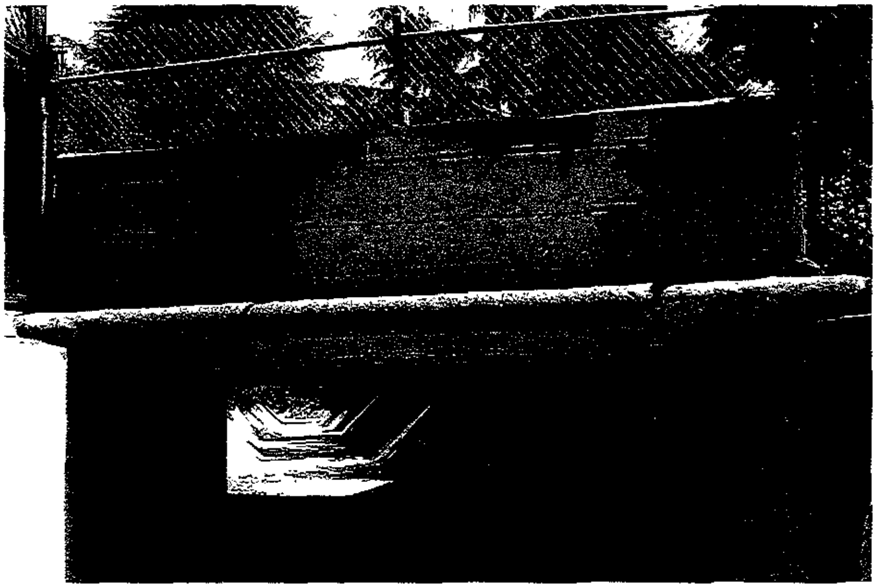
Conclusions and Recommendations:

The overall condition of the channel is good.

Structural Life Expectancy: 15-20 yrs



H 1A Picture #1



H 1A Picture #2

SUMMARY REPORT OF SITE INVESTIGATION

General Information:

Creek Name: Hale Creek	*SCVWD Reach No.*: H 1B
Location: Mt. View Ave. to Arroyo Rd.	*Channel Type*: Concrete Trapezoidal
Date of Original Construction: 1960	*Date of Inspection*: 7/28/99

General Dimensions:

Channel Height: Ranges from 6.5ft to 8.4ft	*Convention*: Looking Up-Station
Channel Width at Top: Ranges from 9.3ft to 22.3ft	*Channel Slope Left*: Ranges from 1:1 to 0.5:1
Channel Width at Bottom: Ranges from 9.3ft to 10ft	*Channel Slope Right*: Ranges from 1:1 to 0.5:1

General Condition of Reach:

CONCERNS	*GENERAL REMARKS*
Concrete Cracks	Moderate separation cracks between wall and slab were found sporadically throughout the reach.
Surface Defects	Moderate spalling was found on wall and/or invert at two separate joints. See Picture #1. Moderate pop-outs were found at the base of the channel lining at three separate locations along the reach. See Picture #2.
Reinforcement	Moderate to minor exposed reinforcement found at seven separate locations along the reach. See Picture #3. At one location, the reinforcement was intentionally exposed.
Structural Deformation	None detected.
Soil Stability	N/A
Other	N/A

General Condition of Channel for Future Structural Repair/Modification:

Spatial Limitations for Any Repair/Modification	Utility conduit crosses channel at the Mt. View culvert. Fences and sporadic vegetation were found on both sides of the channel throughout the reach. See Picture #4.

Summary and Conclusions:

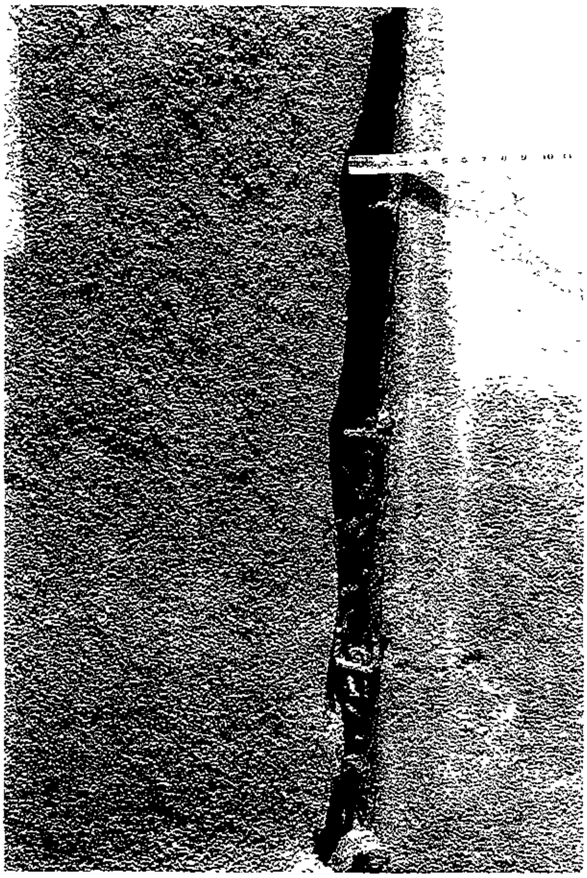
Summary of Investigation:

Moderate spalling was found at the wall and/or invert at two joints. The spalling may be due to pounding of adjacent channel sections during a seismic event. Moderate pop-outs with exposed reinforcement can be attributed to the lack of concrete cover. The separation cracks between the wall and slab is most likely due to abrasion.

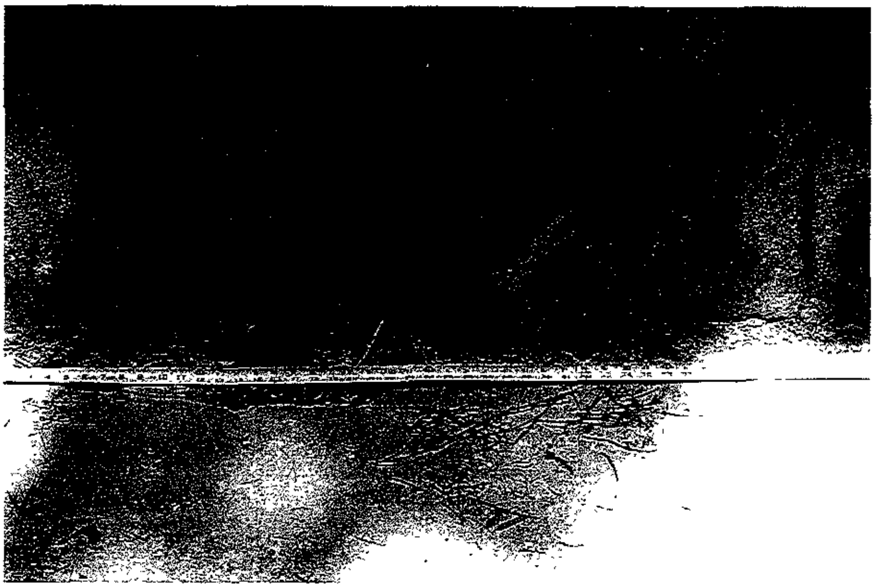
Conclusions and Recommendations:

Reach H 1B has incurred some damage during its service life. However, most of the damage incurred to date does not threaten the overall structural integrity of the channel.

Structural Life Expectancy: 15-20 yrs (Trap. Channel only) 20-25 yrs (Box Culvert)



H 1B Picture #1



H 1B Picture #2

H 1B Picture #3

H 1B Picture #4

SUMMARY REPORT OF SITE INVESTIGATION

General Information:

Creek Name: Hale Creek	*SCVWD Reach No.*: H 2A
Location: Arroyo Rd. to Marilyn Dr.	*Channel Type*: Concrete Trapezoidal
Date of Original Construction: 1960	*Date of Inspection*: 7/28/99

General Dimensions:

Channel Height: Ranges from 6.5ft to 8ft	*Convention*: Looking Up-Station
Channel Width at Top: Ranges from 12ft to 15.5ft	*Channel Slope Left*: Mostly 0.5:1
Channel Width at Bottom: Varies from 9.8ft to 12ft	*Channel Slope Right*: Mostly 0.5:1

General Condition of Reach:

CONCERNS	*GENERAL REMARKS*
Concrete Cracks	Moderate horizontal and vertical temperature cracks were found along 50% of the reach. See Picture #1.
Surface Defects	Moderate spalling was found at three separate joints. An example is shown in Picture #2. Moderate disintegration of the invert slab was found at one location, minor delamination was encountered at another section of channel lining. The delamination of the lining is shown in Picture #3.
Reinforcement	Moderate to minor exposed reinforcement was found at two separate joint locations.
Structural Deformation	None detected.
Soil Stability	There are possibly two voids within the reach. Both are behind the channel lining (adjacent to a weep hole or opened joint). See Pictures #4 and #5.
Other	N/A

General Condition of Channel for Future Structural Repair/Modification:

Spatial Limitations for Any Repair/Modification	Utility conduits cross channel at Arroyo Rd. and Marilyn Dr. box culverts. Fences on both sides of channel (approx. 2ft offset from top of walls).

Summary and Conclusions:

Summary of Investigation:

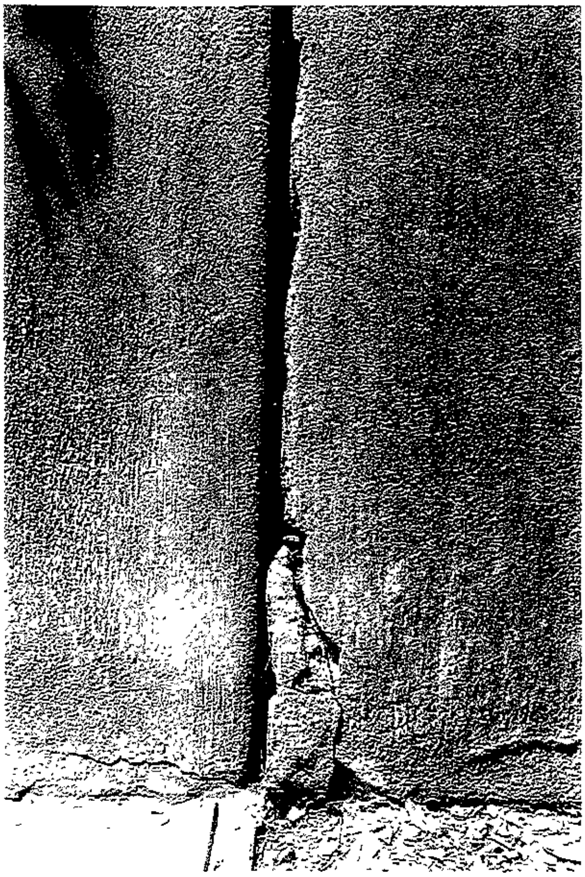
The moderate cracks found along 50% of the reach are due to unaccounted for loads resisted by the channel lining. The moderate disintegration of the invert slab and minor delamination of the channel lining are surface defects considered insignificant because such surface defects are expected to occur during the service life of the channel. The moderate spalling and/or opening at the joints (exposing reinforcement) is most likely due to pounding or separation of adjacent channel sections during a seismic event. The concrete cracks and spalls incurred by the channel will reduce its structural life expectancy. The possible voids behind the channel lining should be further investigated because such voids may lead to sinkholes and/or property damage.

Conclusions and Recommendations:

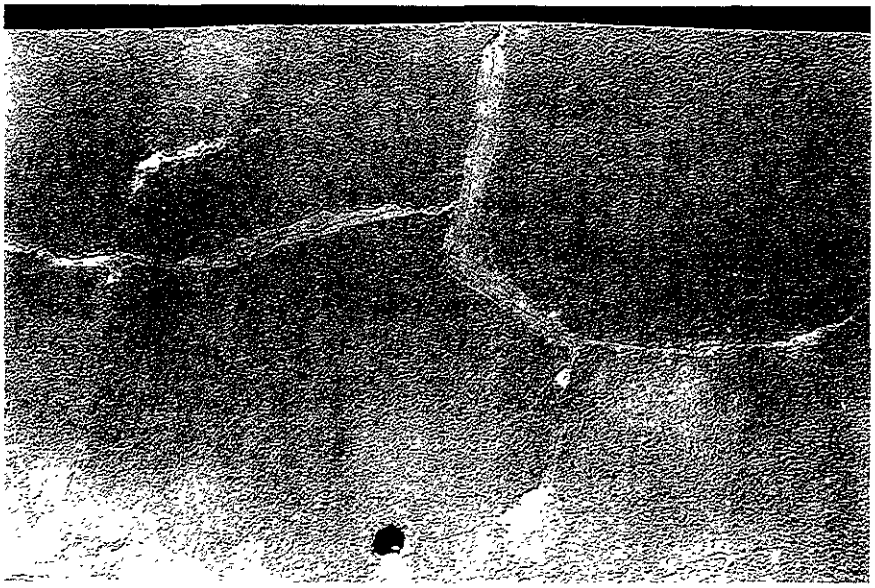
Since the channel has incurred the damage specified above, we recommend the replacement of the trapezoidal channel lining for reach H 2A within the next 10 years.

Structural Life Expectancy: 5-10 yrs (Trap. Channel only) 20-25 yrs (Box Culvert)

H 2A Picture #1

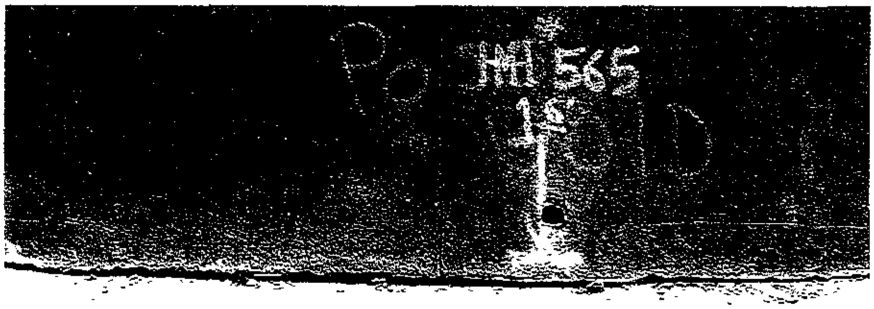


H 2A Picture #2



H 2A Picture #3

H 2A Picture #4



H 2A Picture #5

SUMMARY REPORT OF SITE INVESTIGATION

General Information:

Creek Name: Hale Creek	*SCVWD Reach No.*: H 2B
Location: Marilyn Dr. to Sunshine Dr. North	*Channel Type*: Concrete Trapezoidal
Date of Original Construction: 1960	*Date of Inspection*: 7/28/99

General Dimensions:

Channel Height: Ranges from 5.75ft to 7.75ft	*Convention*: Looking Up-Station
Channel Width at Top: Ranges from 9.75ft to 23ft	*Channel Slope Left*: Varies from 0.25:1 to 1:1
Channel Width at Bottom: Ranges from 9.75 to 10ft	*Channel Slope Right*: Varies from 0.5:1 to 1:1

General Condition of Reach:

CONCERNS	*GENERAL REMARKS*
Concrete Cracks	Moderate horizontal and vertical temperature cracks found along the entire reach. See Pictures #1 and #2 for typical examples.
Surface Defects	Moderate pop-outs were found at the base of the channel lining (at one location only). See Picture #3.
Reinforcement	Moderate exposed reinforcement found at the same location as the moderate pop-outs. See Picture #3.
Structural Deformation	None detected.
Soil Stability	N/A
Other	N/A

General Condition of Channel for Future Structural Repair/Modification:

Spatial Limitations for Any Repair/Modification	Three inch diameter pipe crosses channel at one location. Fence found on both sides of channel throughout reach (approx. 2ft offset from top of lining).

Summary and Conclusions:

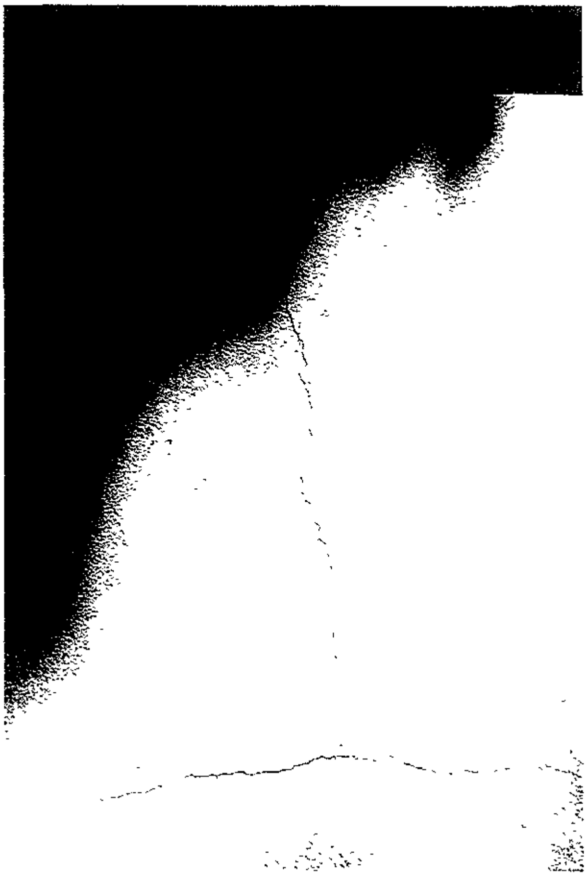
Summary of Investigation:

The moderate cracks found along the reach are due to unaccounted for loads resisted by the channel lining. The moderate pop-outs and exposed reinforcement at the one location along the reach is due to the lack of concrete cover over the reinforcement. The concrete cracks incurred by the channel will reduce its structural life expectancy.

Conclusions and Recommendations:

Since the channel has incurred the damage specified above, we recommend the replacement of the trapezoidal channel lining for reach H 2B within the next 10 years.

Structural Life Expectancy: 5-10 yrs (Trap. Channel only) 20-25 yrs (Box Culvert)



H 2B Picture #1

H 2B Picture #2

H 2B Picture #3

SUMMARY REPORT OF SITE INVESTIGATION

General Information:

Creek Name: Hale Creek	*SCVWD Reach No.*: H 3A
Location: Sunshine Dr. (N) to Sunshine Dr. (S)	*Channel Type*: Concrete Trapezoidal
Date of Original Construction: 1960	*Date of Inspection*: 7/28/99

General Dimensions:

Channel Height: Mostly 6.5ft	*Convention*: Looking Up-Station
Channel Width at Top: Ranges from 12ft to 16.3ft	*Channel Slope Left*: 0.5:1
Channel Width at Bottom: Ranges from 9.8ft to 12ft	*Channel Slope Right*: 0.5:1

General Condition of Reach:

CONCERNS	*GENERAL REMARKS*
Concrete Cracks	Moderate horizontal and vertical cracks were found along the entire reach. See Picture #1. Moderate nonstructural direct impact cracks were found at one location. See Picture #2.
Surface Defects	Moderate spalling found at two separate joints. See Picture #3. Moderate pop-out found at one location. See Picture #4.
Reinforcement	Moderate exposed reinforcement found at two locations. See Pictures #4 and #5.
Structural Deformation	None detected.
Soil Stability	Possible void behind channel lining. See Picture #2.
Other	N/A

General Condition of Channel for Future Structural Repair/Modification:

Spatial Limitations for Any Repair/Modification	Fence found on both sides of channel (approx. 2ft offset from walls).

Summary and Conclusions:

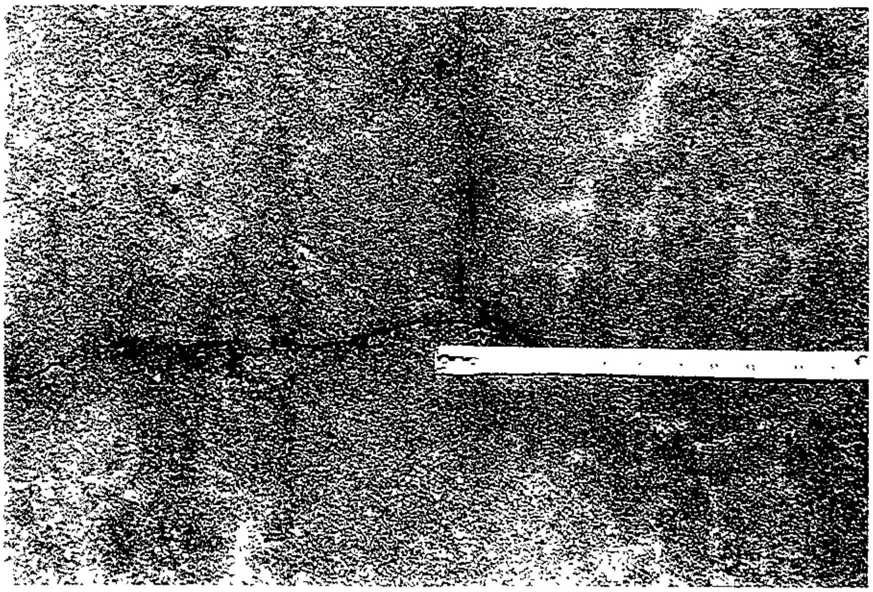
Summary of Investigation:

The moderate horizontal and vertical cracks found along the reach are due to unaccounted for loads resisted by the channel lining. These concrete cracks will reduce the structural life expectancy of the channel. The moderate pop-out and exposed reinforcement is due to the lack of concrete cover over the reinforcement. The moderate spalling at the joints (exposing a dowel) is most likely due to pounding of adjacent channel sections during a seismic event. The possible void(s) behind the channel lining should be further investigated because such a void(s) may lead to sinkholes and/or significant property damage.

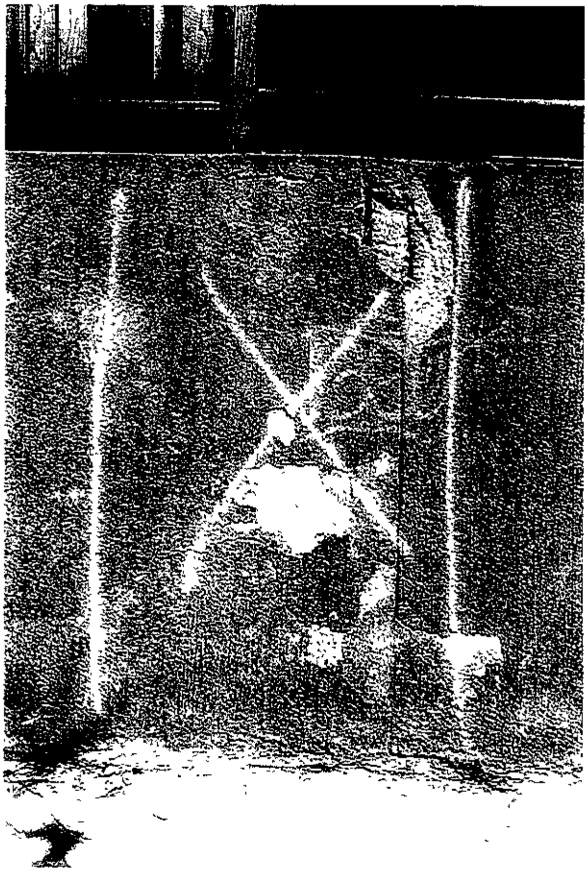
Conclusions and Recommendations:

Since the channel has incurred the damage specified above, we recommend the replacement of the trapezoidal channel lining for reach H 3A within the next 10 years.

Structural Life Expectancy: 5-10 yrs (Trap. Channel only) 20-25 yrs (Box Culvert)

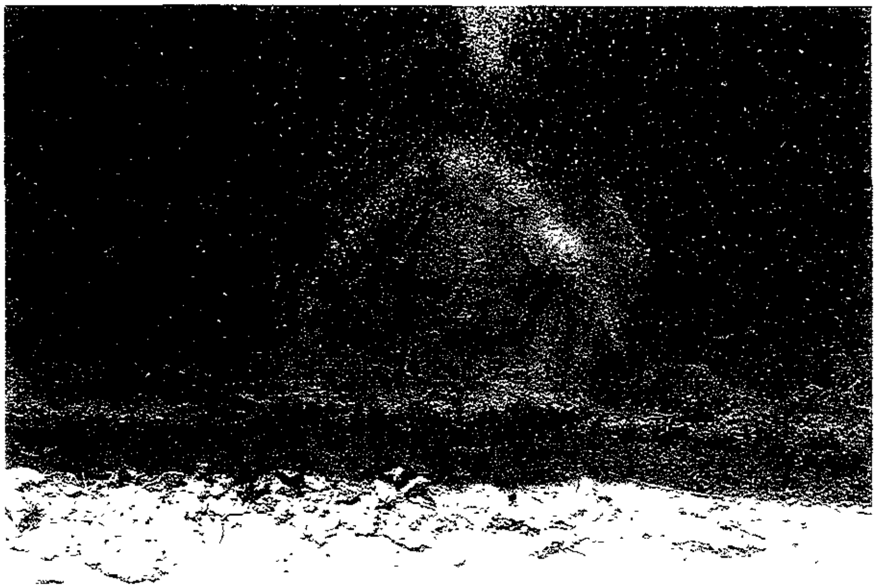


H 3A Picture #1

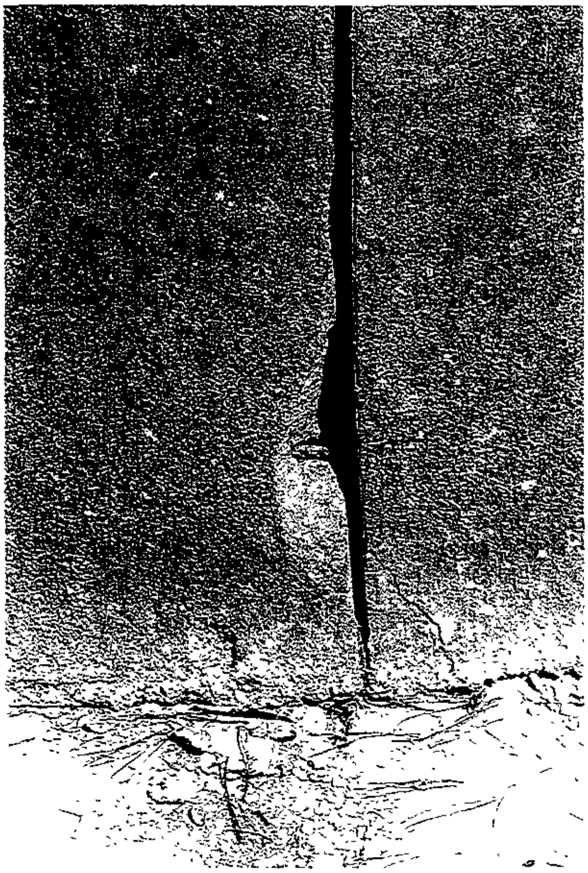


H 3A Picture #2

H 3A Picture #3



H 3A Picture #4



H 3A Picture #5

SUMMARY REPORT OF SITE INVESTIGATION

General Information:

Creek Name: Hale Creek	*SCVWD Reach No.*: H 3B
Location: Sunshine Dr. (S) to Springer Rd.	*Channel Type*: Concrete Trapezoidal
Date of Original Construction: 1960	*Date of Inspection*: 7/28/99

General Dimensions:

Channel Height: Ranges from 6.5ft to 7.25ft	*Convention*: Looking Up-Station
Channel Width at Top: Ranges from 12ft to 16.75ft	*Channel Slope Left*: 0.5:1
Channel Width at Bottom: Ranges from 10ft to 12ft	*Channel Slope Right*: 0.5:1

General Condition of Reach:

CONCERNS	*GENERAL REMARKS*
Concrete Cracks	Moderate horizontal and vertical cracks were found along the entire reach.
Surface Defects	Moderate spalling was found at two separate joints. See Picture #1. Moderate delamination on the invert slab was found at one location. See Picture #2.
Reinforcement	Moderate exposed reinforcement was found at one joint. See Picture #3.
Structural Deformation	None detected.
Soil Stability	N/A
Other	N/A

General Condition of Channel for Future Structural Repair/Modification:

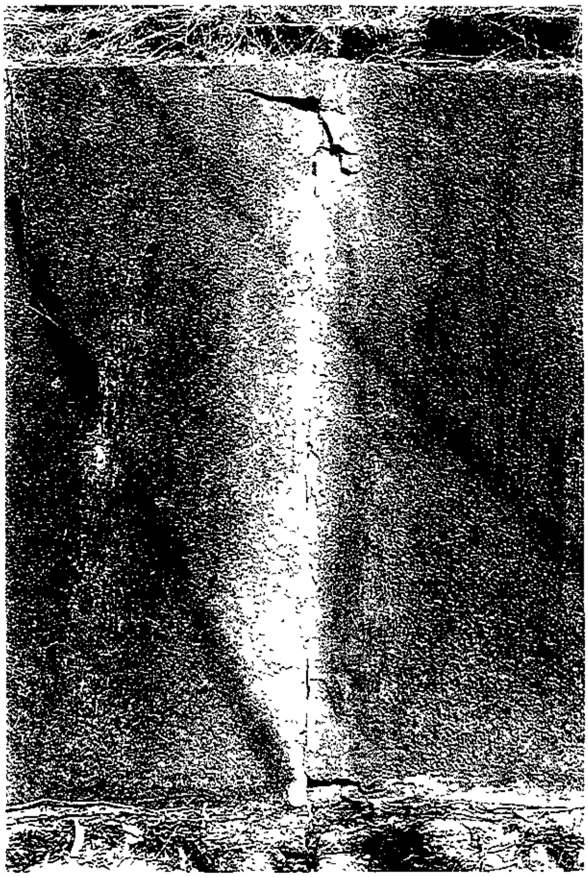
Spatial Limitations for Any Repair/Modification	Fence on both sides of channel (approx. 1ft offset from top of walls).

Summary and Conclusions:

Summary of Investigation:
The moderate horizontal and vertical cracks found along the reach are due to unaccounted for loads resisted by the channel lining. These concrete cracks will reduce the structural life expectancy of the channel. The moderate spalling at the joints (exposing a dowel) is most likely due to pounding of adjacent channel sections during a seismic event. The moderate delamination of the invert slab is considered insignificant because such a surface defect is expected to occur during the service life of the channel.

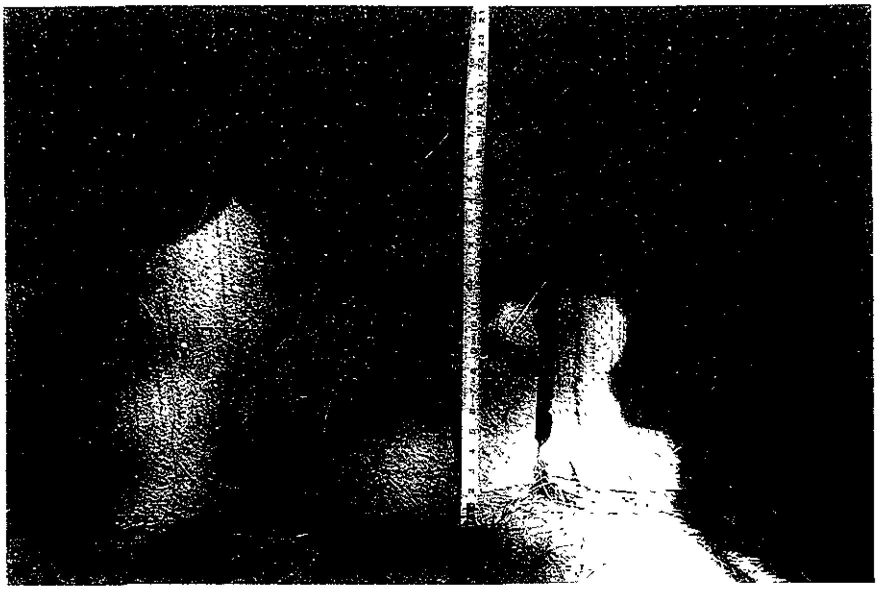
Conclusions and Recommendations:
Since the channel has incurred the damage specified above, we recommend the replacement of the trapezoidal channel lining for reach H 3B within the next 10 years.

Structural Life Expectancy: 5-10 yrs (Trap. Channel only) 20-25 yrs (Box Culvert)



H 3B Picture #1

H 3B Picture #2



H 3B Picture #3

SUMMARY REPORT OF SITE INVESTIGATION

General Information:

Creek Name: Hale Creek	*SCVWD Reach No.*: H 4
Location: Springer Rd. to Cuesta Dr.	*Channel Type*: Concrete Trapezoidal
Date of Original Construction: 1960	*Date of Inspection*: 7/28/99

General Dimensions:

Channel Height: Ranges from 6.3ft to 7.7 ft	*Convention*: Looking Up-Station
Channel Width at Top: Ranges from 12ft to 18.8ft	*Channel Slope Left*: 0.5:1
Channel Width at Bottom: Ranges from 10ft to 12ft	*Channel Slope Right*: 0.5:1

General Condition of Reach:

CONCERNS	*GENERAL REMARKS*
Concrete Cracks	Moderate horizontal and vertical cracks were found along the entire reach. Moderate separation crack was found between the wall and invert. See Picture #1.
Surface Defects	Moderate pop-outs were found at one location. See Picture #2. Moderate spalling was found at two joints. See Picture #3. Moderate abrasion was found on the invert slab for approximately 5% of the reach. See Picture #4.
Reinforcement	Moderate exposed reinforcement was found at one location. See Picture #2.
Structural Deformation	None detected.
Soil Stability	N/A
Other	N/A

General Condition of Channel for Future Structural Repair/Modification:

Spatial Limitations for Any Repair/Modification	Fence found on both sides of channel (approx. 1ft to 2ft offset from walls).

Summary and Conclusions:

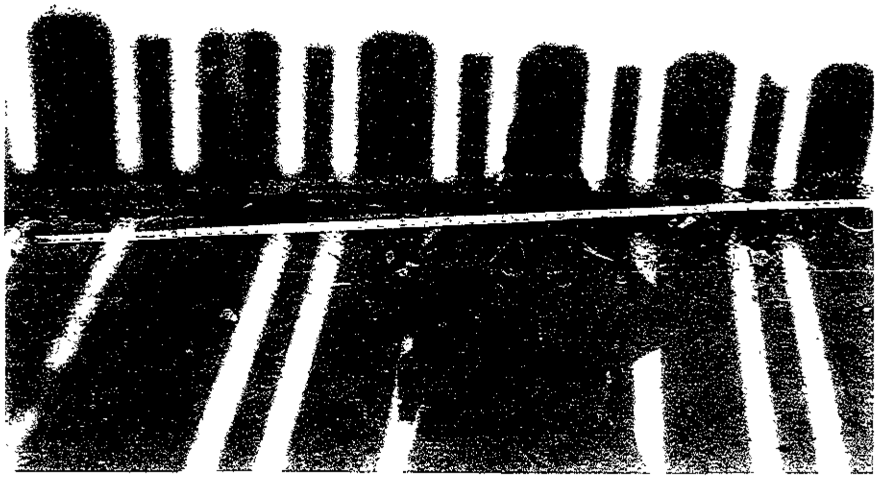
Summary of Investigation:

The moderate horizontal and vertical cracks found along the reach are due to unaccounted for loads resisted by the channel lining. These concrete cracks will reduce the structural life expectancy of the channel. The moderate spalling at the joints is most likely due to pounding of adjacent channel sections during a seismic event. The moderate abrasion of the invert slab is considered insignificant because such a surface defect is expected to occur during the service life of the channel. The moderate pop-outs and exposed reinforcement is due to the lack of concrete cover over the reinforcement.

Conclusions and Recommendations:

Since the channel has incurred the damage specified above, we recommend the replacement of the trapezoidal channel lining for reach H 4 within the next 10 years.

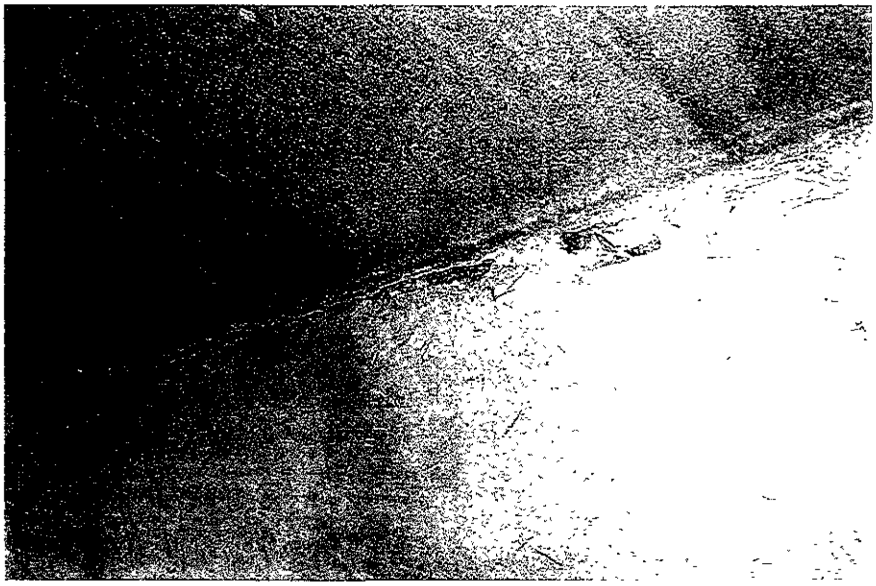
Structural Life Expectancy: 5-10 yrs (Trap. Channel only) 20-25 yrs (Box Culvert)



H 4 Picture #1

H 4 Picture #2

H 4 Picture #3



H 4 Picture #4

SUMMARY REPORT OF SITE INVESTIGATION

General Information:

Creek Name: Hale Creek	*SCVWD Reach No.*: H 5A
Location: Cuesta Dr. to Arboleda Dr.	*Channel Type*: Mostly Concrete Trapezoidal
Date of Original Construction: 1960	*Date of Inspection*: 7/29/99

General Dimensions:

Channel Height: Ranges from 6ft to 7.4ft	*Convention*: Looking Up-Station
Channel Width at Top: Ranges from 10ft to 16.3ft	*Channel Slope Left*: 0.5:1
Channel Width at Bottom: Ranges from 10ft to 12ft	*Channel Slope Right*: 0.5:1

General Condition of Reach:

CONCERNS	*GENERAL REMARKS*
Concrete Cracks	Moderate horizontal and vertical cracks were found along the entire reach. Three separation cracks between the wall and invert were found. See Picture #1.
Surface Defects	Severe disintegration was found at two separation cracks (see Picture #2) while moderate scaling was found at the other. Moderate spalling and pop-outs were found at one joint. See Pictures #3 and #4.
Reinforcement	Severe to moderate exposed reinforcement was found at the separation cracks and at one joint. See Picture #2 and #3.
Structural Deformation	None detected.
Soil Stability	N/A.
Other	N/A

General Condition of Channel for Future Structural Repair/Modification:

Spatial Limitations for Any Repair/Modification	Fence found on both sides of channel (approx. 2ft offset from walls.)

Summary and Conclusions:

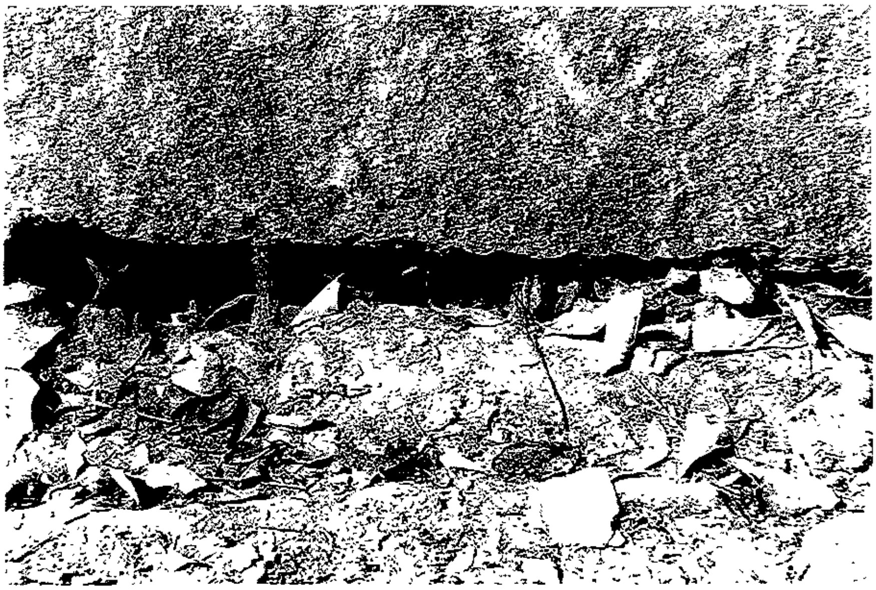
Summary of Investigation:

The moderate horizontal and vertical cracks found along the reach are due to unaccounted for loads resisted by the channel lining. These concrete cracks will reduce the structural life expectancy of the channel. The disintegration and scaling found at the reach may be significant locally, but globally, they do not significantly effect the reach's overall structural integrity. The spalling and exposed reinforcement found at one joint are most likely due to pounding of adjacent channel sections during a seismic event.

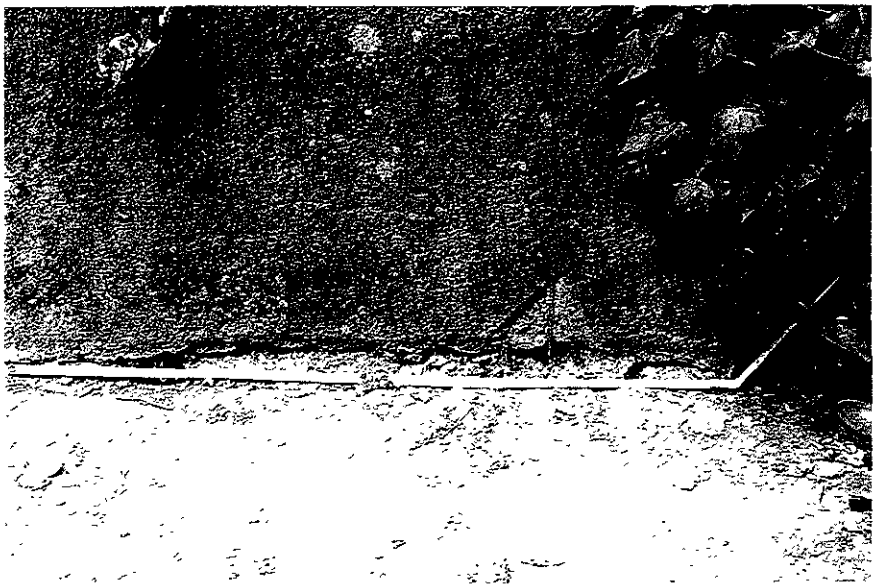
Conclusions and Recommendations:

Since the channel has incurred the damage specified above, we recommend the replacement of the trapezoidal channel lining for reach H 5A within the next 10 years.

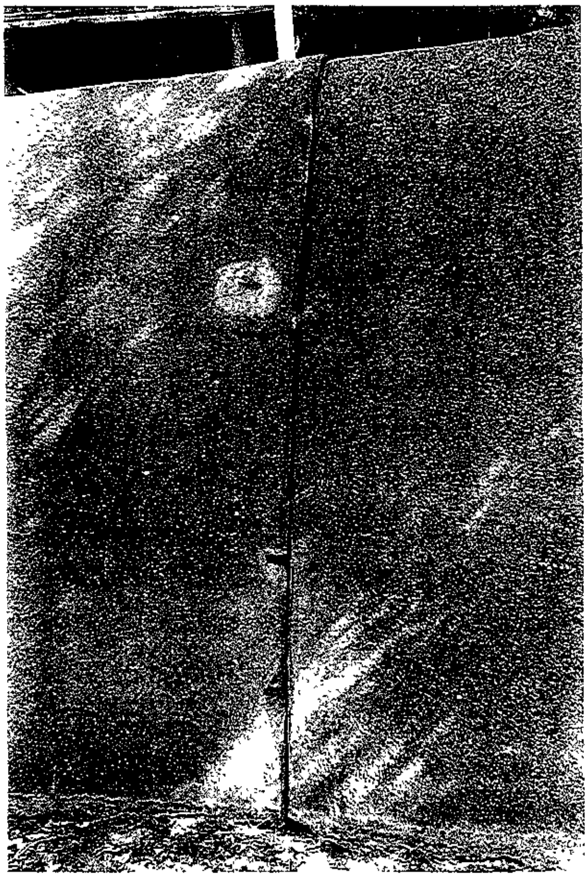
Structural Life Expectancy: 5-10 yrs (Trap. Channel only) 20-25 yrs (Box Culvert)



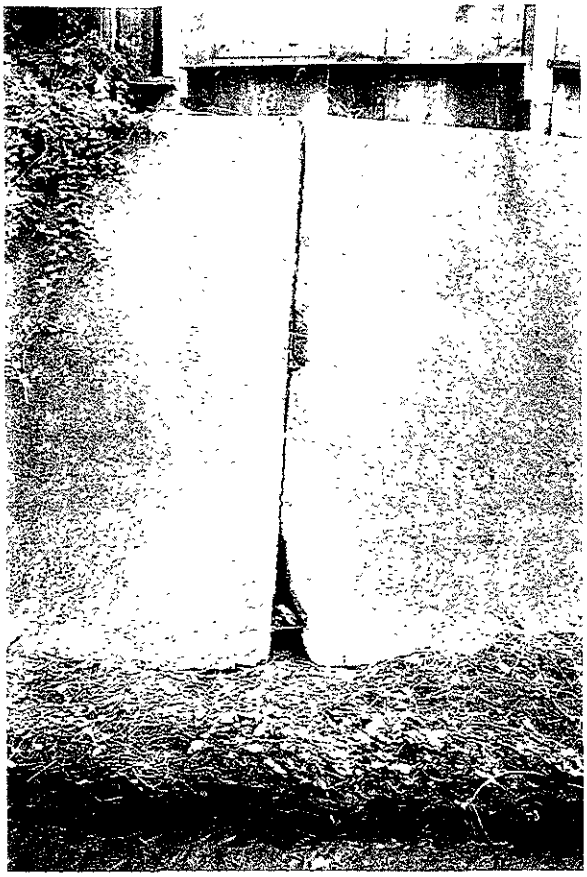
H 5A Picture #1



H 5A Picture #2



H 5A Picture #3



H 5A Picture #4

SUMMARY REPORT OF SITE INVESTIGATION

General Information:

Creek Name: Hale Creek	*SCVWD Reach No.*: H 5B
Location: Arboleda Dr. to Rosita Ave.	*Channel Type*: Concrete U-Frame
Date of Original Construction: 1960	*Date of Inspection*: 7/29/99

General Dimensions:

Channel Height: Mostly 7.25ft	*Convention*: Looking Up-Station
Channel Width at Top: 10ft	*Channel Slope Left*: N/A
Channel Width at Bottom: 10ft	*Channel Slope Right*: N/A

General Condition of Reach:

CONCERNS	*GENERAL REMARKS*
Concrete Cracks	Moderate vertical shrinkage cracks on both walls throughout the reach. Severe flexural cracks along the invert slab on 45% of reach. See Picture #1.
Surface Defects	Minor to moderate pop-outs on 45% of reach. See Picture #2. Moderate spalling at two joints.
Reinforcement	Minor to moderate exposed reinforcement on 45% of reach. See Picture #2.
Structural Deformation	Severe wall deflections on 70% of reach. Max. deflection found to be 9.7 times yield displacement. See Picture #3.
Soil Stability	N/A
Other	N/A

General Condition of Channel for Future Structural Repair/Modification:

Spatial Limitations for Any Repair/Modification	Chain link fence above both walls throughout the reach, Springer Road (approx. 10ft offset from left wall) and utilities and bridges (timber or steel) spanning the channel periodically. See Picture #4.

Summary and Conclusions:

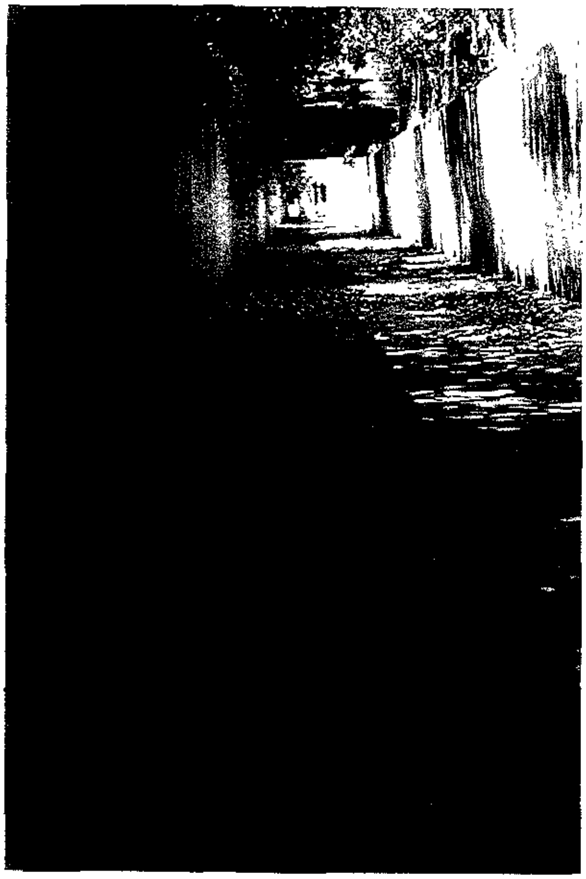
Summary of Investigation:

Excessive wall deflections have been detected for both walls for approximately 70% of the reach. Two severe flexural cracks can be found along the invert, each approximately 340ft long and 2.5ft from the face of each wall. These severe flexural cracks are due to excessive wall deflection and poor reinforcement details. The pop-outs and exposed reinforcement along the reach can be attributed to the lack of concrete cover for the wall reinforcement (found to be on the order of 0 to 1/2 inch). Moderate spalling is found at two joints. The spalling may be due to pounding of adjacent channel sections during a seismic event.

Conclusions and Recommendations:

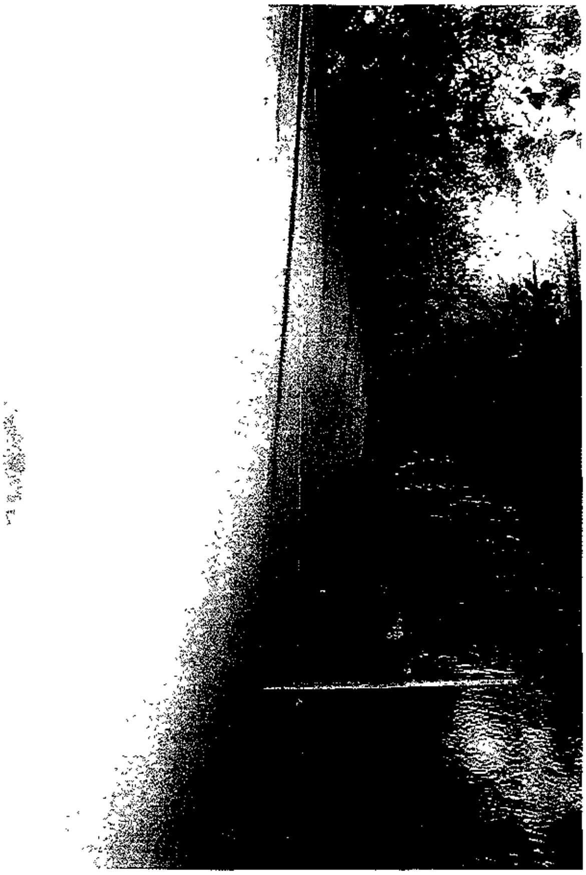
Since approximately 70% of the reach's vertical walls have sustained severe wall deflections and poor reinforcing details exist within the invert, we recommend the rehabilitation of the existing U-Frame channel for reach H 5B within the next 5 years.

Structural Life Expectancy: 0-5 yrs (Trap. Channel only) 20-25 yrs (Box Culvert)



H 5B Picture #1

H 5B Picture #2



H 5B Picture #3

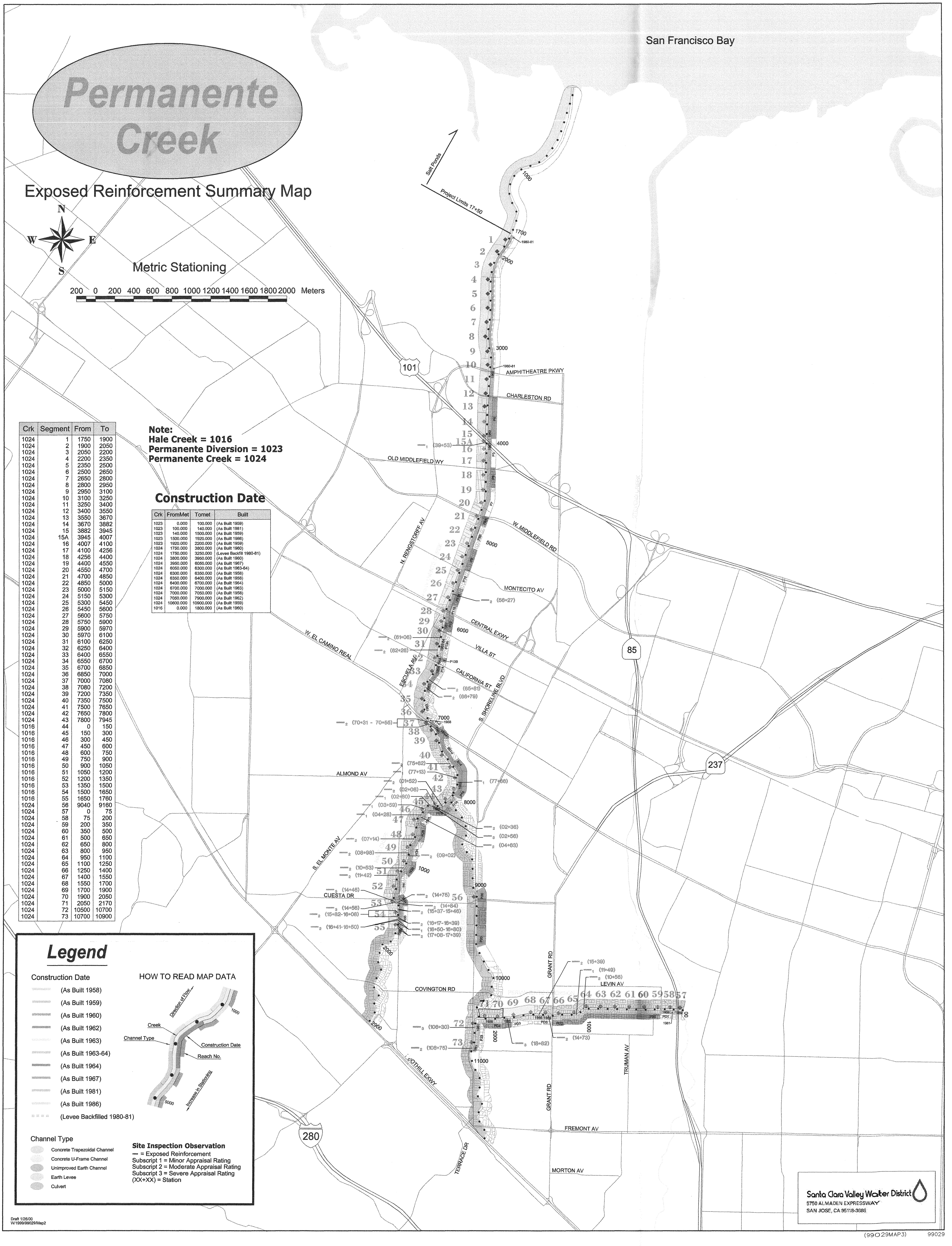
H 5B Picture #4

Appendix B

Summary Maps

Permanente Creek

Exposed Reinforcement Summary Map



Note:
Hale Creek = 1016
Permanente Diversion = 1023
Permanente Creek = 1024

Crk	Segment	From	To
1024	1	1750	1900
1024	2	1900	2050
1024	3	2050	2200
1024	4	2200	2350
1024	5	2350	2500
1024	6	2500	2650
1024	7	2650	2800
1024	8	2800	2950
1024	9	2950	3100
1024	10	3100	3250
1024	11	3250	3400
1024	12	3400	3550
1024	13	3550	3670
1024	14	3670	3882
1024	15	3882	3945
1024	15A	3945	4007
1024	16	4007	4100
1024	17	4100	4256
1024	18	4256	4400
1024	19	4400	4550
1024	20	4550	4700
1024	21	4700	4850
1024	22	4850	5000
1024	23	5000	5150
1024	24	5150	5300
1024	25	5300	5450
1024	26	5450	5600
1024	27	5600	5750
1024	28	5750	5900
1024	29	5900	5970
1024	30	5970	6100
1024	31	6100	6250
1024	32	6250	6400
1024	33	6400	6550
1024	34	6550	6700
1024	35	6700	6850
1024	36	6850	7000
1024	37	7000	7080
1024	38	7080	7200
1024	39	7200	7350
1024	40	7350	7500
1024	41	7500	7650
1024	42	7650	7800
1024	43	7800	7945
1016	44	0	150
1016	45	150	300
1016	46	300	450
1016	47	450	600
1016	48	600	750
1016	49	750	900
1016	50	900	1050
1016	51	1050	1200
1016	52	1200	1350
1016	53	1350	1500
1016	54	1500	1650
1016	55	1650	1760
1024	56	9040	9160
1024	57	0	75
1024	58	75	200
1024	59	200	350
1024	60	350	500
1024	61	500	650
1024	62	650	800
1024	63	800	950
1024	64	950	1100
1024	65	1100	1250
1024	66	1250	1400
1024	67	1400	1550
1024	68	1550	1700
1024	69	1700	1900
1024	70	1900	2050
1024	71	2050	2170
1024	72	10500	10700
1024	73	10700	10900

Construction Date

Crk	FromMet	Tomet	Built
1023	0.000	100.000	(As Built 1959)
1023	100.000	140.000	(As Built 1981)
1023	140.000	1500.000	(As Built 1959)
1023	1500.000	1920.000	(As Built 1986)
1023	1920.000	2200.000	(As Built 1959)
1024	1750.000	3800.000	(As Built 1960)
1024	1750.000	3250.000	(Levee Backfill 1980-81)
1024	3800.000	3950.000	(As Built 1960)
1024	3950.000	6050.000	(As Built 1967)
1024	6050.000	6300.000	(As Built 1963-64)
1024	6300.000	6350.000	(As Built 1958)
1024	6350.000	6400.000	(As Built 1958)
1024	6400.000	6700.000	(As Built 1964)
1024	6700.000	7000.000	(As Built 1963)
1024	7000.000	7050.000	(As Built 1958)
1024	7050.000	7900.000	(As Built 1962)
1024	10600.000	10900.000	(As Built 1959)
1016	0.000	1800.000	(As Built 1960)

Legend

Construction Date

▨ (As Built 1958)
▨ (As Built 1959)
▨ (As Built 1960)
▨ (As Built 1962)
▨ (As Built 1963)
▨ (As Built 1963-64)
▨ (As Built 1964)
▨ (As Built 1967)
▨ (As Built 1981)
▨ (As Built 1986)
▨ (Levee Backfilled 1980-81)

HOW TO READ MAP DATA

Direction of Flow
Creek
Channel Type
Construction Date
Reach No.
Increase in Stationing
1000
5000

Channel Type

● Concrete Trapezoidal Channel
● Concrete U-Frame Channel
● Unimproved Earth Channel
● Earth Levee
● Culvert

Site Inspection Observation
═ = Exposed Reinforcement
Subscript 1 = Minor Appraisal Rating
Subscript 2 = Moderate Appraisal Rating
Subscript 3 = Severe Appraisal Rating
(XX+XX) = Station

Draft 1/26/00
W/1999/99029/Map2

Santa Clara Valley Water District
5750 ALMADEN EXPRESSWAY
SAN JOSE, CA 95118-3686

Permanente Creek

Surface Defect Summary Map

Note:
Hale Creek = 1016
Permanente Diversion = 1023
Permanente Creek = 1024

Crk	Segment	From	To
1024	1	1750	1900
1024	2	1900	2050
1024	3	2050	2200
1024	4	2200	2350
1024	5	2350	2500
1024	6	2500	2650
1024	7	2650	2800
1024	8	2800	2950
1024	9	2950	3100
1024	10	3100	3250
1024	11	3250	3400
1024	12	3400	3550
1024	13	3550	3670
1024	14	3670	3882
1024	15	3882	3945
1024	15A	3945	4007
1024	16	4007	4100
1024	17	4100	4256
1024	18	4256	4400
1024	19	4400	4550
1024	20	4550	4700
1024	21	4700	4850
1024	22	4850	5000
1024	23	5000	5150
1024	24	5150	5300
1024	25	5300	5450
1024	26	5450	5600
1024	27	5600	5750
1024	28	5750	5900
1024	29	5900	5970
1024	30	5970	6100
1024	31	6100	6250
1024	32	6250	6400
1024	33	6400	6550
1024	34	6550	6700
1024	35	6700	6850
1024	36	6850	7000
1024	37	7000	7080
1024	38	7080	7200
1024	39	7200	7350
1024	40	7350	7500
1024	41	7500	7650
1024	42	7650	7800
1024	43	7800	7945
1016	44	0	150
1016	45	150	300
1016	46	300	450
1016	47	450	600
1016	48	600	750
1016	49	750	900
1016	50	900	1050
1016	51	1050	1200
1016	52	1200	1350
1016	53	1350	1500
1016	54	1500	1650
1016	55	1650	1760
1024	56	9040	9160
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1024	66	1250	1400
1024	67	1400	1550
1024	68	1550	1700
1024	69	1700	1900
1024	70	1900	2050
1024	71	2050	2170
1024	72	10500	10700
1024	73	10700	10900

Construction Date

Crk	FromMet	Tomet	Built
1023	0.000	100.000	(As Built 1959)
1023	100.000	140.000	(As Built 1981)
1023	140.000	1500.000	(As Built 1959)
1023	1500.000	1920.000	(As Built 1986)
1023	1920.000	2200.000	(As Built 1959)
1024	1750.000	3800.000	(As Built 1960)
1024	1750.000	3250.000	(Levee Backfill 1980-81)
1024	3800.000	3950.000	(As Built 1960)
1024	3950.000	6050.000	(As Built 1967)
1024	6050.000	6300.000	(As Built 1963-64)
1024	6300.000	6350.000	(As Built 1958)
1024	6350.000	6400.000	(As Built 1958)
1024	6400.000	6700.000	(As Built 1964)
1024	6700.000	7000.000	(As Built 1963)
1024	7000.000	7050.000	(As Built 1958)
1024	7050.000	7900.000	(As Built 1962)
1024	10600.000	10900.000	(As Built 1959)
1016	0.000	1800.000	(As Built 1960)

Legend

Construction Date

- (As Built 1958)
- (As Built 1959)
- (As Built 1960)
- (As Built 1962)
- (As Built 1963)
- (As Built 1963-64)
- (As Built 1964)
- (As Built 1967)
- (As Built 1981)
- (As Built 1986)
- (Levee Backfilled 1980-81)

Channel Type

- Concrete Trapezoidal Channel
- Concrete U-Frame Channel
- Unimproved Earth Channel
- Earth Levee
- Culvert

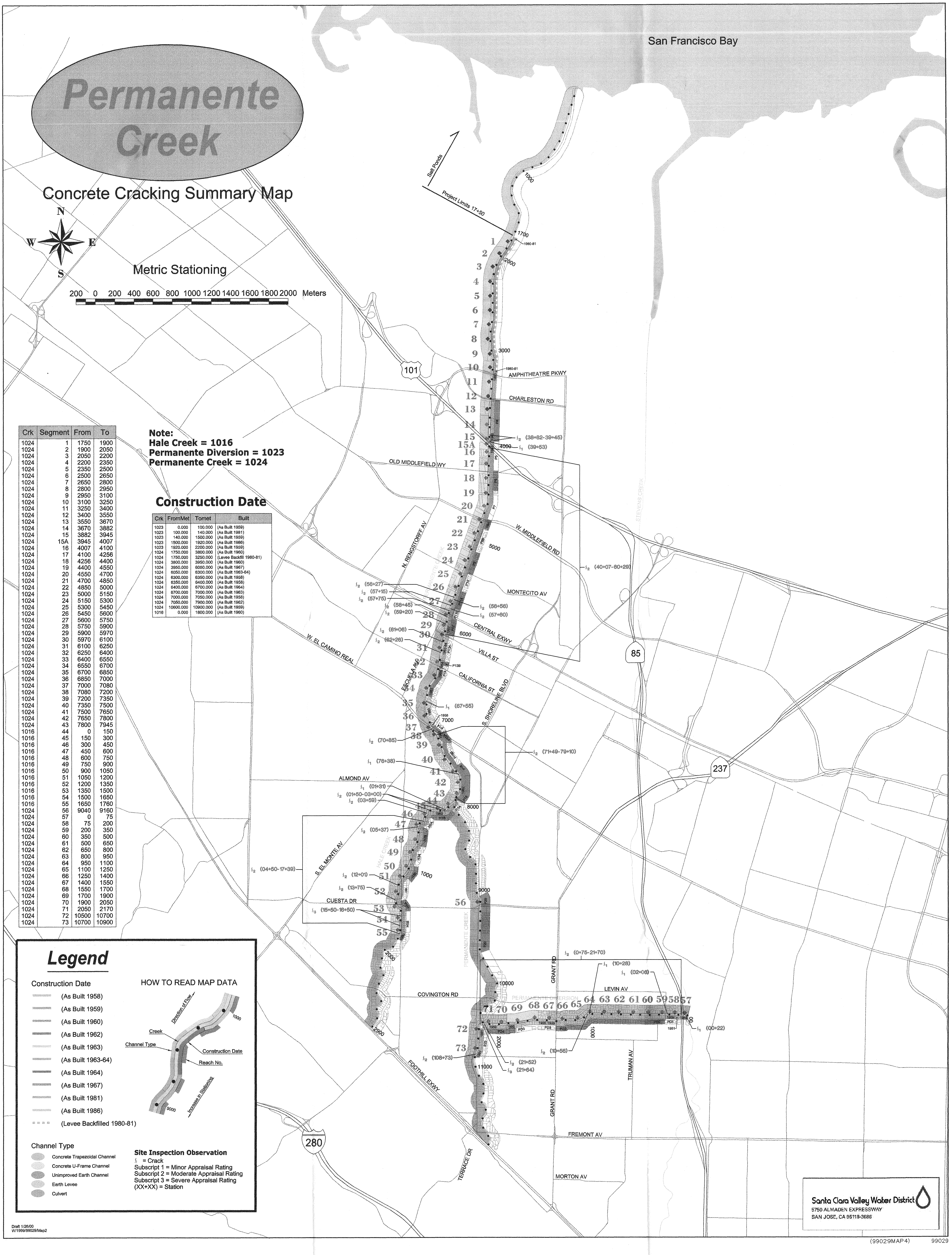
Site Inspection Observation
▥ = Surface Defect
Subscript 1 = Minor Appraisal Rating
Subscript 2 = Moderate Appraisal Rating
Subscript 3 = Severe Appraisal Rating
(XX+XX) = Station

Santa Clara Valley Water District
5750 ALMADEN EXPRESSWAY
SAN JOSE, CA 95118-3686

Draft 1/26/00
W/1999/99029/Map2

Permanente Creek

Concrete Cracking Summary Map



Crk	Segment	From	To
1024	1	1750	1900
1024	2	1900	2050
1024	3	2050	2200
1024	4	2200	2350
1024	5	2350	2500
1024	6	2500	2650
1024	7	2650	2800
1024	8	2800	2950
1024	9	2950	3100
1024	10	3100	3250
1024	11	3250	3400
1024	12	3400	3550
1024	13	3550	3670
1024	14	3670	3882
1024	15	3882	3945
1024	15A	3945	4007
1024	16	4007	4100
1024	17	4100	4256
1024	18	4256	4400
1024	19	4400	4550
1024	20	4550	4700
1024	21	4700	4850
1024	22	4850	5000
1024	23	5000	5150
1024	24	5150	5300
1024	25	5300	5450
1024	26	5450	5600
1024	27	5600	5750
1024	28	5750	5900
1024	29	5900	5970
1024	30	5970	6100
1024	31	6100	6250
1024	32	6250	6400
1024	33	6400	6550
1024	34	6550	6700
1024	35	6700	6850
1024	36	6850	7000
1024	37	7000	7080
1024	38	7080	7200
1024	39	7200	7350
1024	40	7350	7500
1024	41	7500	7650
1024	42	7650	7800
1024	43	7800	7945
1016	44	0	150
1016	45	150	300
1016	46	300	450
1016	47	450	600
1016	48	600	750
1016	49	750	900
1016	50	900	1050
1016	51	1050	1200
1016	52	1200	1350
1016	53	1350	1500
1016	54	1500	1650
1016	55	1650	1760
1024	56	9040	9160
1024	57	0	75
1024	58	75	200
1024	59	200	350
1024	60	350	500
1024	61	500	650
1024	62	650	800
1024	63	800	950
1024	64	950	1100
1024	65	1100	1250
1024	66	1250	1400
1024	67	1400	1550
1024	68	1550	1700
1024	69	1700	1900
1024	70	1900	2050
1024	71	2050	2170
1024	72	10500	10700
1024	73	10700	10900

Note:
Hale Creek = 1016
Permanente Diversion = 1023
Permanente Creek = 1024

Construction Date

Crk	FromMet	Tomet	Built
1023	0.000	100.000	(As Built 1959)
1023	100.000	140.000	(As Built 1981)
1023	140.000	1500.000	(As Built 1959)
1023	1500.000	1920.000	(As Built 1986)
1023	1920.000	2200.000	(As Built 1959)
1024	1750.000	3800.000	(As Built 1960)
1024	1750.000	3250.000	(Levee Backfill 1980-81)
1024	3800.000	3950.000	(As Built 1960)
1024	3950.000	6050.000	(As Built 1967)
1024	6050.000	6300.000	(As Built 1963-64)
1024	6300.000	6350.000	(As Built 1958)
1024	6350.000	6400.000	(As Built 1958)
1024	6400.000	6700.000	(As Built 1964)
1024	6700.000	7000.000	(As Built 1963)
1024	7000.000	7050.000	(As Built 1958)
1024	7050.000	7900.000	(As Built 1962)
1024	10600.000	10900.000	(As Built 1959)
1016	0.000	1800.000	(As Built 1960)

Legend

Construction Date

- (As Built 1958)
- (As Built 1959)
- (As Built 1960)
- (As Built 1962)
- (As Built 1963)
- (As Built 1963-64)
- (As Built 1964)
- (As Built 1967)
- (As Built 1981)
- (As Built 1986)
- (Levee Backfilled 1980-81)

HOW TO READ MAP DATA

Channel Type

- Concrete Trapezoidal Channel
- Concrete U-Frame Channel
- Unimproved Earth Channel
- Earth Levee
- Culvert

Site Inspection Observation
S = Crack
Subscript 1 = Minor Appraisal Rating
Subscript 2 = Moderate Appraisal Rating
Subscript 3 = Severe Appraisal Rating
(XX+XX) = Station

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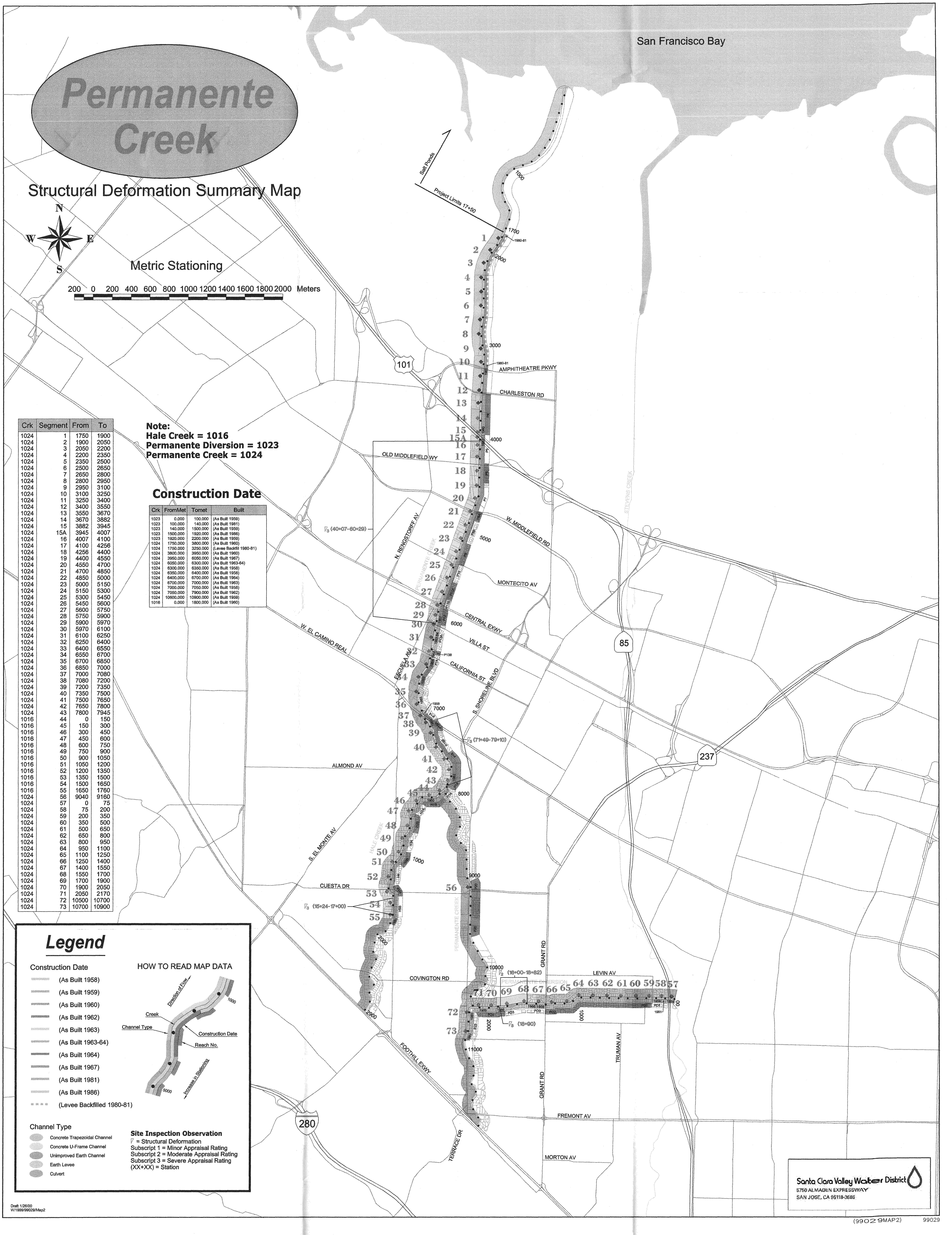
Santa Clara Valley Water District
5750 ALMADEN EXPRESSWAY
SAN JOSE, CA 95118-3686

Permanente Creek

Structural Deformation Summary Map



Note:
Hale Creek = 1016
Permanente Diversion = 1023
Permanente Creek = 1024

Crk	Segment	From	To
1024	1	1750	1900
1024	2	1900	2050
1024	3	2050	2200
1024	4	2200	2350
1024	5	2350	2500
1024	6	2500	2650
1024	7	2650	2800
1024	8	2800	2950
1024	9	2950	3100
1024	10	3100	3250
1024	11	3250	3400
1024	12	3400	3550
1024	13	3550	3670
1024	14	3670	3882
1024	15	3882	3945
1024	15A	3945	4007
1024	16	4007	4100
1024	17	4100	4256
1024	18	4256	4400
1024	19	4400	4550
1024	20	4550	4700
1024	21	4700	4850
1024	22	4850	5000
1024	23	5000	5150
1024	24	5150	5300
1024	25	5300	5450
1024	26	5450	5600
1024	27	5600	5750
1024	28	5750	5900
1024	29	5900	5970
1024	30	5970	6100
1024	31	6100	6250
1024	32	6250	6400
1024	33	6400	6550
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1024	42	7650	7800
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1016	47	450	600
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1016	49	750	900
1016	50	900	1050
1016	51	1050	1200
1016	52	1200	1350
1016	53	1350	1500
1016	54	1500	1650
1016	55	1650	1760
1024	56	9040	9160
1024	57	0	75
1024	58	75	200
1024	59	200	350
1024	60	350	500
1024	61	500	650
1024	62	650	800
1024	63	800	950
1024	64	950	1100
1024	65	1100	1250
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1024	67	1400	1550
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1024	69	1700	1900
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Construction Date

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1024	6350.000	6400.000	(As Built 1958)
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1024	6700.000	7000.000	(As Built 1963)
1024	7000.000	7050.000	(As Built 1958)
1024	7050.000	7900.000	(As Built 1962)
1024	10600.000	10900.000	(As Built 1959)
1016	0.000	1800.000	(As Built 1960)

Legend

Construction Date

- (As Built 1958)
- (As Built 1959)
- (As Built 1960)
- (As Built 1962)
- (As Built 1963)
- (As Built 1963-64)
- (As Built 1964)
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- (Levee Backfilled 1980-81)

HOW TO READ MAP DATA

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Santa Clara Valley Water District
5750 ALMADEN EXPRESSWAY
SAN JOSE, CA 95118-3686

Permanente Creek

Test Result Summary Map

Note:
Hale Creek = 1016
Permanente Diversion = 1023
Permanente Creek = 1024

Crk	Segment	From	To
1024	1	1750	1900
1024	2	1900	2050
1024	3	2050	2200
1024	4	2200	2350
1024	5	2350	2500
1024	6	2500	2650
1024	7	2650	2800
1024	8	2800	2950
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1024	24	5150	5300
1024	25	5300	5450
1024	26	5450	5600
1024	27	5600	5750
1024	28	5750	5900
1024	29	5900	5970
1024	30	5970	6100
1024	31	6100	6250
1024	32	6250	6400
1024	33	6400	6550
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1024	7000.000	7050.000	(As Built 1958)
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1024	10600.000	10900.000	(As Built 1959)
1016	0.000	1800.000	(As Built 1960)

Coring Test Summary Table

Sample ID	Creek	Station	Core Length (in)	As Built Wall Thickness (in)	Actual Cover (in)	As Built Cover (in)	Concrete Strength		
							ASTM C-42 (psi)	Schmidt Hammer (psi)	As Built (psi)
A1	Perm.	40+07	7.00	8.00	1.75	2.00	8440	8100	-
A2	Perm.	43+05	8.50	8.00	1.50	2.00	9870	7300	-
A3	Perm.	46+07	8.50	8.00	1.50	2.00	4470	7800	-
A4	Perm.	47+86	7.75	8.00	1.75	2.00	6030	6800	-
A5	Perm.	49+14	8.75	8.00	1.75	2.00	6410	7800	-
A6	Perm.	51+10	9.50	8.00	2.00	2.00	6780	6800	-
A7	Perm.	52+19	8.50	8.00	1.25	2.00	7290	7300	-
A8	Perm.	55+24	10.50	8.00	2.25	2.00	5490	7300	-
A9	Perm.	73+26	8.00	8.00	2.25	2.00	7800	6800	-
A10	Perm.	75+00	8.00	8.00	1.75	2.00	4530	5700	-
A11	Perm.	75+00	8.00	8.00	1.75	2.00	4150	8100	-
A12	Perm.	76+80	10.00	8.00	1.75	2.00	5530	7600	-
A13	Perm.	76+80	11.00	8.00	1.75	2.00	6410	7300	-
A14	Perm.	79+32	7.00	5.50	2.25	2.50	4290	6600	-
B4	Perm. Div.	12+19	5.00	4.00	-	2.00	5030	6600	-
B6	Perm. Div.	18+29	10.00	10.00	2.50	2.00	4400	8100	3000
B7	Perm. Div.	18+90	4.75	4.00	2.00	2.00	4400	5700	3000
B8	Perm. Div.	21+52	11.25	9.00	1.75	1.50	8420	7300	-
B9	Perm. Div.	21+64	10.50	9.00	1.75	1.50	7760	6400	-
B10	Perm.	108+00	7.50	6.00	3.00	2.50	5790	6200	-
C1	Hale	07+55	6.50	5.50	1.75	-	6030	5200	-
C4	Hale	16+70	12.00	8.50	1.25	2.44	4770	7800	-
C5	Hale	17+00	13.25	8.50	1.25	2.44	5560	7800	-
C6	Hale	17+00	11.00	8.50	1.50	2.44	5130	7000	-

Half Cell Potential Test Summary Table

Test Location	Creek	Station	Deficiency Tested	Half Cell Potential Test Readings	V&A Consulting Engineers Conclusion
1	Hale	05+00	At Vertical Crack in Wall	-128 to -299 mV	Corrosion Suspected
2	Hale	01+52	At Base of Wall Exposed Rebar	-61 to -214 mV	No Corrosion Apparent
3	Hale	09+15	At Possible Void in Wall and Cracks	-158 to -375 mV	Corrosion Suspected
4	Perm. Div.	03+79	At Horizontal and Vertical Cracks in Lining	-300 to -426 mV	Corrosion Suspected
5	Perm. Div.	10+67	At Horizontal and Vertical Cracks in Lining	-95 to -445 mV	Corrosion Suspected
6	Perm. Div.	16+17	At Vertical Wall Cracks with Staining	77 to -151 mV	No Corrosion Apparent
7	Hale	16+00	At Longitudinal Crack in Invert Slab	66 to -134 mV	No Corrosion Apparent
8	Perm.	75+00	At Base of East Wall for Main Wall Steel	-100 to -342 mV	Corrosion Suspected
9	Perm.	78+70	At Base of East Wall for Main Wall Steel	-225 to -321 mV	Corrosion Uncertain
10	Perm.	78+70	At Base of West Wall for Main Wall Steel	-212 to -415 mV	Corrosion Suspected

Note: The conclusions were based on the ASTM C876 guidelines and adjusted for conditions experienced during the testing.

Log of Test Borings

Boring Number	Creek	Station	Soil Classification Behind Channel Lining or Wall
P-1	Perm.	75+60	Poorly graded sand with silt, silty sand
H-1	Hale	01+10	Fat clay, clayey sand
H-2	Hale	05+37	Lean clay, clayey sand
H-3	Hale	09+60	Sandy lean clay
H-4	Hale	15+24	Lean clay
D-1	Perm. Div.	02+40	Poorly graded sand with silt and gravel, clayey sand with gravel, sandy lean clay
D-2	Perm. Div.	06+10	Sandy lean clay
D-3	Perm. Div.	10+20	Clayey gravel, lean clay with sand, clayey sand
D-4	Perm. Div.	15+50	Sandy lean clay, clayey sand, lean clay
D-5	Perm. Div.	17+80	Lean clay with sand, sandy lean clay, silty sand with gravel

Note: The soil classification is listed in the order that they were found. The classification of the samples were visually verified according to the United Soil Classification System.

Santa Clara Valley Water District
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Permanente Creek

Deficiency Pattern Summary Map

PERMANENTE CREEK - STRUCTURAL INTEGRITY STUDY

Summary of Deficiencies

1) Excessive Wall Deflections
- Water intrusion into the concrete section at the base of the wall is possibly caused by one or a combination of the following reasons:
  1) The original design underestimated the design loads causing a tension crack at the back face base of the wall allowing for water intrusion. Based on a paper in the Journal of the Soil Mechanics and Foundations Division, Leo Casagrande February, 1973, design loads for cantilever retaining walls may increase to double the active load value towards at-rest earth loading at saturated fine backfill material or at consolidated granular backfill material.
  2) Over time, deterioration of the construction joint between the wall and invert of the U-wall sections allows for water intrusion into concrete section at base of wall.
  3) The as-built details reveal that the existing thickness of the invert slab is insufficient to develop the main wall reinforcing, which effectively reduces the capacity of the wall. The insufficient bar development promotes concrete cracks at the base of the wall / invert connection.
- Water intrusion corrodes the main vertical wall steel.
- Corroded main vertical wall steel weakens wall-retaining capacity causing the wall to rotate and excessive wall deflections at the top of the wall to form.
- When the remaining main vertical wall steel completely corrodes, the wall will rotate further and possibly collapse.

2) Longitudinal Cracking of the Invert
- The as-built details reveal insufficient lengths (3-feet) of reinforcing steel in the inverts to carry the negative moment from the wall / invert connection completely into the invert slab.
- The negative moment from the active pressure on the wall is being carried into the invert slab for about 2'-6" to 3'-0" where the negative moment reinforcing effectively terminates thus creating a longitudinal flexural failure crack the invert slab.
- This longitudinal flexural failure crack in the invert releases the rotational restraint on the walls and the walls rotate and deflect inward.
- Moisture will eventually penetrate through the flexural crack and corrode the remaining nominal invert steel, which is effectively doweling the rotated wall to the invert preventing a complete sheared release at the crack.
- When the remaining nominal invert steel completely corrodes, the wall will rotate further and possibly collapse.

3) Trapezoidal Channel Lining Deterioration
- The trapezoidal channel walls were apparently designed only as a slope lining and were not intended to retain any significant earth pressures.
- The thickened channel lip at the top of the wall acts as a stiffening beam. This condition along with the design active earth loading behind the wall effectively allows the wall to span from the top of the wall to the base of the wall.
- The typical 4-inch thick wall with 6x6-6x6 welded wire fabric (or #4 @12" each way) does not have sufficient flexural capacity to withstand the active earth pressure. This condition produces a horizontal crack located approximately between a third to a half of the wall height from the invert slab.
- The lack of sufficient horizontal wall steel and the horizontal flexural crack in the wall promotes vertical temperature expansion and contraction cracks to form.
- These vertical temperature expansion and contraction cracks occur at approximately 4 to 8 feet on center and propagating from the horizontal flexural crack.
- These cracks allow moisture to corrode the wall steel. The corroding steel expands and spalls off the concrete cover (commonly half the thickness of the wall).

4) Vertical Temperature Expansion and Contraction Cracks in Walls
- U-walls of approximately 7 feet and greater tend to exhibit vertical temperature expansion and contraction cracks propagating down from the top of the wall at 4 to 8 feet centers, commonly aligning with the spacing of the weeps.
- The reason these cracks would occur on the taller walls are two-fold:
  1) Minimal / insufficient horizontal wall steel for the given length of the wall between expansion joints.
  2) Not being influenced by the restraining effects of the invert slab at the bottom of the wall, the top of these walls is freer to expand and contract.
- Where irrigation occurs behind the wall, the runoff water seeps through the vertical cracks and causes efflorescence from the cracks. Indicating corrosion of the wall steel.
- The corrosion of the wall steel in time further weakens the wall against temperature expansion and contraction and promotes further cracking.

5) Spillage of Backfill and Foundation Material Through Weepholes and Wall Gaps (See Note 1)
- Apparent deterioration of the weephole screens and gaps in the channel structure allow for spillage of backfill and foundation material.
- As the channel waters rise and fall, the water flows through the weepholes and channel gaps and saturates the backfill material. As the channel water elevation drops, the water flows back out the weepholes and channel gaps carrying with it portions of the backfill and foundation material.
- Over a period of time and cycles, all of the crushed rock directly behind the weepholes get removed and depending on the soil type (clay or sands) two things would occur:
  1) In sandy backfill, the backfill material would continue to permeate through the weephole and eventually create a void and sinkhole behind the wall. The void may also occur beneath the invert slab causing loss of support and possible collapse of the invert into the void.
  2) In clayey backfill, the backfill material would partially fill the holes allowing vegetation growth and eventually clogging the weepholes allowing for unaccounted additional hydrostatic wall pressure. This additional hydrostatic wall pressure may lead to Deficiency Number 1 - Excessive Wall Deflections.

6) Exposed Reinforcement Due to Lack of Concrete Cover
- Initial poor construction quality may have led to insufficient concrete cover over the wall reinforcing.
- Exposure to the elements over time deteriorates the concrete enough to cause spalling of the concrete cover at various locations.
- The exposed reinforcing corrodes and expands causing further concrete spalling.

7) Wall Expansion Joint Deterioration (See Note 2)
- Deterioration of wall expansion joint material due to time and weathering causes the expansion joint material to fall out and wash away.
- Possible past seismic events may have opened the wall gaps further or pounded the wall edges at the gaps together.
- The wall movements contribute to spalls of the concrete at the pounded edges and at the wall dowels.
- Debris in the channel waters over the wall gaps further abrades and spalls the concrete at the edge and corrodes the steel wall dowels.
- The corroding steel wall dowels expand and spall off the concrete cover.
- The large gaps in the walls at the expansion joints allow backfill material to sift through the wall.
- The loss of backfill material creates earth voids and sink holes behind the wall.

Notes:
1. This deficiency is denoted on the map at locations were we suspect it has already occurred - However this deficiency may occur anywhere along the investigated alignment.
2. This deficiency is not denoted on the map however, the deficiency affects the entire investigated alignment.

Santa Clara Valley Water District
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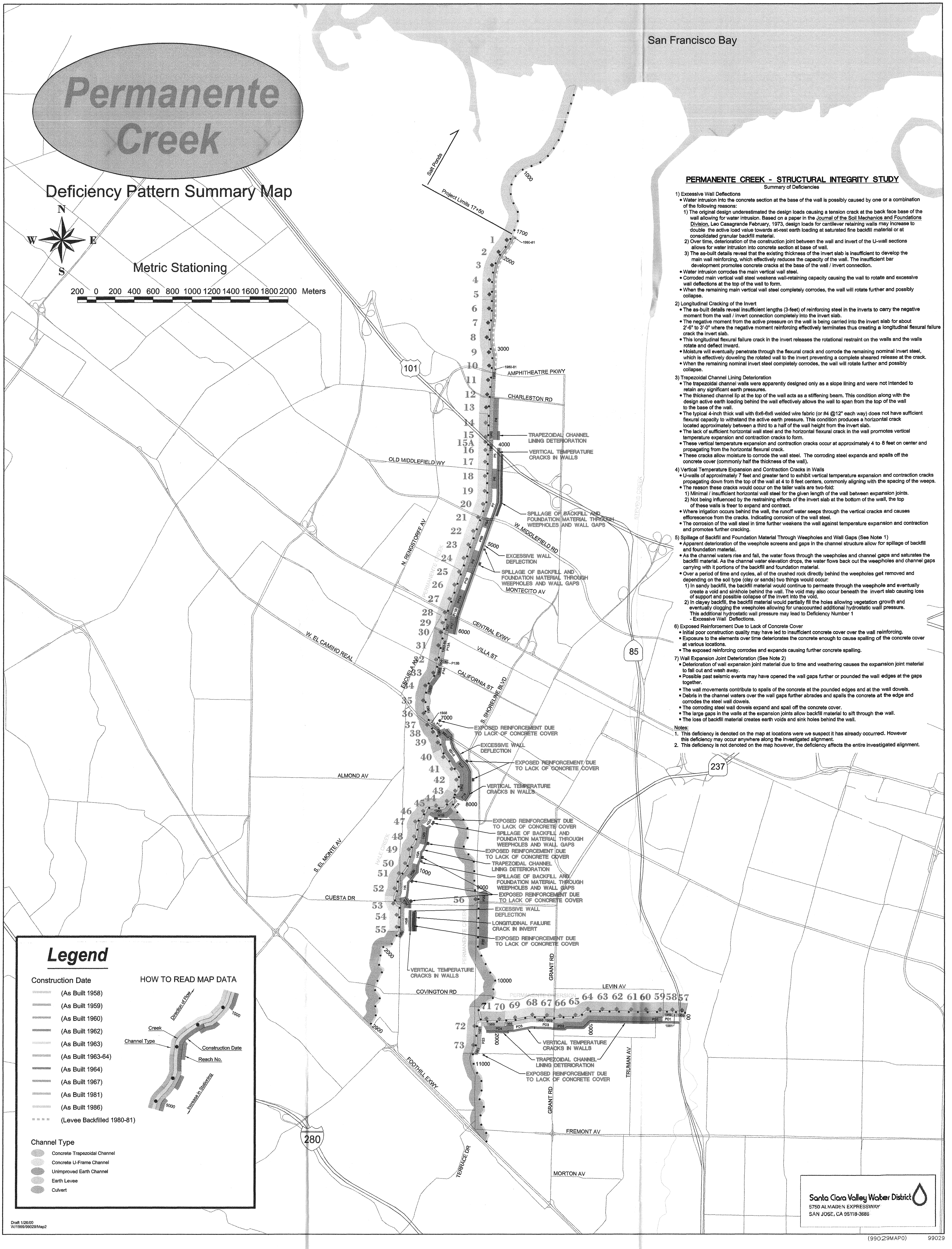
Permanente Creek

Deficiency Pattern Summary Map


San Francisco Bay
Salt Ponds
Project Limits 17+50
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Metric Stationing
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1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 15A 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48 49 50 51 52 53 54 55 56
57 58 59 60 61 62 63 64 65 66 67 68 69 70 71 72 73
101
85
237
280
AMPHITHEATRE PKWY
CHARLESTON RD
OLD MIDDLEFIELD WY
W. MIDDLEFIELD RD
MONTECITO AV
N. RENGSTORFF AV
CENTRAL EXWY
VILLA ST
CALIFORNIA ST
S. SHORELINE BLVD
ESCUELA AV
W. EL CAMINO REAL
ALMOND AV
S. EL MONTE AV
CUESTA DR
COVINGTON RD
LEVIN AV
GRANT RD
TRUMAN AV
FREMONT AV
MORTON AV
FOOTHILL EXWY
TERRACE DR
STEVENS CREEK
HALE CREEK
PERMANENTE CREEK
PERMANENTE DIVERSION
P13B
P14
P15B
P16
P20
H1A
H1B
H2A
H2B
H3A
H3B
H4
H5A
H5B
PD1
PD2
PD3
PD4
1958
1959
1960
1962
1963
1964
1981
1986
TRAPEZOIDAL CHANNEL LINING DETERIORATION
VERTICAL TEMPERATURE CRACKS IN WALLS
SPILLAGE OF BACKFILL AND FOUNDATION MATERIAL THROUGH WEEPHOLES AND WALL GAPS
EXCESSIVE WALL DEFLECTION
SPILLAGE OF BACKFILL AND FOUNDATION MATERIAL THROUGH WEEPHOLES AND WALL GAPS
EXPOSED REINFORCEMENT DUE TO LACK OF CONCRETE COVER
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EXCESSIVE WALL DEFLECTION
LONGITUDINAL FAILURE CRACK IN INVERT
EXPOSED REINFORCEMENT DUE TO LACK OF CONCRETE COVER
VERTICAL TEMPERATURE CRACKS IN WALLS
VERTICAL TEMPERATURE CRACKS IN WALLS
TRAPEZOIDAL CHANNEL LINING DETERIORATION
EXPOSED REINFORCEMENT DUE TO LACK OF CONCRETE COVER
HOW TO READ MAP DATA
Direction of Flow
Creek
Channel Type
Construction Date
Reach No.
Increase in Stationing
1000
5000

Legend

Construction Date

- (As Built 1958)
- (As Built 1959)
- (As Built 1960)
- (As Built 1962)
- (As Built 1963)
- (As Built 1963-64)
- (As Built 1964)
- (As Built 1967)
- (As Built 1981)
- (As Built 1986)
- (Levee Backfilled 1980-81)

Channel Type

- Concrete Trapezoidal Channel
- Concrete U-Frame Channel
- Unimproved Earth Channel
- Earth Levee
- Culvert

PERMANENTE CREEK - STRUCTURAL INTEGRITY STUDY

Summary of Deficiencies

1) Excessive Wall Deflections
- Water intrusion into the concrete section at the base of the wall is possibly caused by one or a combination of the following reasons:
  1) The original design underestimated the design loads causing a tension crack at the back face base of the wall allowing for water intrusion. Based on a paper in the Journal of the Soil Mechanics and Foundations Division, Leo Casagrande February, 1973, design loads for cantilever retaining walls may increase to double the active load value towards at-rest earth loading at saturated fine backfill material or at consolidated granular backfill material.
  2) Over time, deterioration of the construction joint between the wall and invert of the U-wall sections allows for water intrusion into concrete section at base of wall.
  3) The as-built details reveal that the existing thickness of the invert slab is insufficient to develop the main wall reinforcing, which effectively reduces the capacity of the wall. The insufficient bar development promotes concrete cracks at the base of the wall / invert connection.
- Water intrusion corrodes the main vertical wall steel.
- Corroded main vertical wall steel weakens wall-retaining capacity causing the wall to rotate and excessive wall deflections at the top of the wall to form.
- When the remaining main vertical wall steel completely corrodes, the wall will rotate further and possibly collapse.

2) Longitudinal Cracking of the Invert
- The as-built details reveal insufficient lengths (3-feet) of reinforcing steel in the inverts to carry the negative moment from the wall / invert connection completely into the invert slab.
- The negative moment from the active pressure on the wall is being carried into the invert slab for about 2'-6" to 3'-0" where the negative moment reinforcing effectively terminates thus creating a longitudinal flexural failure crack the invert slab.
- This longitudinal flexural failure crack in the invert releases the rotational restraint on the walls and the walls rotate and deflect inward.
- Moisture will eventually penetrate through the flexural crack and corrode the remaining nominal invert steel, which is effectively doweling the rotated wall to the invert preventing a complete sheared release at the crack.
- When the remaining nominal invert steel completely corrodes, the wall will rotate further and possibly collapse.

3) Trapezoidal Channel Lining Deterioration
- The trapezoidal channel walls were apparently designed only as a slope lining and were not intended to retain any significant earth pressures.
- The thickened channel lip at the top of the wall acts as a stiffening beam. This condition along with the design active earth loading behind the wall effectively allows the wall to span from the top of the wall to the base of the wall.
- The typical 4-inch thick wall with 6x6-6x6 welded wire fabric (or #4 @12" each way) does not have sufficient flexural capacity to withstand the active earth pressure. This condition produces a horizontal crack located approximately between a third to a half of the wall height from the invert slab.
- The lack of sufficient horizontal wall steel and the horizontal flexural crack in the wall promotes vertical temperature expansion and contraction cracks to form.
- These vertical temperature expansion and contraction cracks occur at approximately 4 to 8 feet on center and propagating from the horizontal flexural crack.
- These cracks allow moisture to corrode the wall steel. The corroding steel expands and spalls off the concrete cover (commonly half the thickness of the wall).

4) Vertical Temperature Expansion and Contraction Cracks in Walls
- U-walls of approximately 7 feet and greater tend to exhibit vertical temperature expansion and contraction cracks propagating down from the top of the wall at 4 to 8 feet centers, commonly aligning with the spacing of the weeps.
- The reason these cracks would occur on the taller walls are two-fold:
  1) Minimal / insufficient horizontal wall steel for the given length of the wall between expansion joints.
  2) Not being influenced by the restraining effects of the invert slab at the bottom of the wall, the top of these walls is freer to expand and contract.
- Where irrigation occurs behind the wall, the runoff water seeps through the vertical cracks and causes efflorescence from the cracks. Indicating corrosion of the wall steel.
- The corrosion of the wall steel in time further weakens the wall against temperature expansion and contraction and promotes further cracking.

5) Spillage of Backfill and Foundation Material Through Weepholes and Wall Gaps (See Note 1)
- Apparent deterioration of the weephole screens and gaps in the channel structure allow for spillage of backfill and foundation material.
- As the channel waters rise and fall, the water flows through the weepholes and channel gaps and saturates the backfill material. As the channel water elevation drops, the water flows back out the weepholes and channel gaps carrying with it portions of the backfill and foundation material.
- Over a period of time and cycles, all of the crushed rock directly behind the weepholes get removed and depending on the soil type (clay or sands) two things would occur:
  1) In sandy backfill, the backfill material would continue to permeate through the weephole and eventually create a void and sinkhole behind the wall. The void may also occur beneath the invert slab causing loss of support and possible collapse of the invert into the void.
  2) In clayey backfill, the backfill material would partially fill the holes allowing vegetation growth and eventually clogging the weepholes allowing for unaccounted additional hydrostatic wall pressure. This additional hydrostatic wall pressure may lead to Deficiency Number 1 - Excessive Wall Deflections.

6) Exposed Reinforcement Due to Lack of Concrete Cover
- Initial poor construction quality may have led to insufficient concrete cover over the wall reinforcing.
- Exposure to the elements over time deteriorates the concrete enough to cause spalling of the concrete cover at various locations.
- The exposed reinforcing corrodes and expands causing further concrete spalling.

7) Wall Expansion Joint Deterioration (See Note 2)
- Deterioration of wall expansion joint material due to time and weathering causes the expansion joint material to fall out and wash away.
- Possible past seismic events may have opened the wall gaps further or pounded the wall edges at the gaps together.
- The wall movements contribute to spalls of the concrete at the pounded edges and at the wall dowels.
- Debris in the channel waters over the wall gaps further abrades and spalls the concrete at the edge and corrodes the steel wall dowels.
- The corroding steel wall dowels expand and spall off the concrete cover.
- The large gaps in the walls at the expansion joints allow backfill material to sift through the wall.
- The loss of backfill material creates earth voids and sink holes behind the wall.

Notes:
1. This deficiency is denoted on the map at locations were we suspect it has already occurred. However this deficiency may occur anywhere along the investigated alignment.
2. This deficiency is not denoted on the map however, the deficiency affects the entire investigated alignment.

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